Appendix F1 – Assessment of Controls (Watershed Restoration Assessment)

WHEEL CREEK
WATER CHEMISTRY MONITORING
YEAR 7 REPORT

Prepared for:

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1.0 INTRODUCTION

Harford County has received a Chesapeake and Atlantic Coastal Bays 2010 Trust Fund grant to address impacts to Wheel Creek through stream restoration, stormwater BMP retrofits, public outreach, and physical, biological, and water chemistry monitoring. Additionally, through mutual agreement with Maryland Department of the Environment (MDE), Wheel Creek has been identified as the County's priority watershed to satisfy National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) monitoring requirements.

Wheel Creek watershed drains 435 acres consisting of high density residential and commercial land uses in the headwaters, and medium and low density residential and forest land uses in the remainder. The stream has been altered by changes in hydrology in the watershed associated with recent urbanization and historical agricultural land use. Imperviousness has increased to 27% in the past three decades of development (Harford County DPW 2008).

Harford County contracted with Versar, Inc., to conduct stormwater runoff monitoring in Wheel Creek to comply, in part, with both the monitoring requirement of the MS4 permit and the monitoring requirements associated with the Chesapeake and Atlantic Coastal Bays 2010 Trust Fund stream restoration initiative. Baseflow monitoring and nutrient synoptic water chemistry sampling were completed by Harford County Department of Public Works (DPW). Long-term flow monitoring, coincident with this monitoring effort at all three of the water chemistry monitoring stations, was conducted by Maryland Department of Natural Resources (DNR) until June 2016, at which point Versar assumed responsibility for the monitoring during the July 1, 2016 to June 30, 2017 monitoring year and moving forward. Maryland DNR also completed a round of pre-restoration biological and physical monitoring each spring and summer since 2009 (Becker 2010). A baseline geomorphological assessment was carried out by the County during January 2010 (KCI Technologies 2010). United States Geological Survey (USGS) operates a stream flow gauging station near the mouth of Wheel Creek (USGS Station 0158175320) and a stage level gauging station and tipping bucket rain gauge in Atkisson Reservoir (USGS Station 01581753).

This report documents the water chemistry monitoring activities undertaken by Harford County, Versar, and USGS, and summarizes the data obtained from July 2016 to June 2017. The activities included capturing nine wet weather events, monthly baseflow monitoring, and nutrient synoptic sampling in the Wheel Creek watershed.

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2.0 STUDY AREA AND STUDY DESIGN

Wheel Creek forms a portion of the Atkisson Reservoir Watershed and resides within the Bush River Basin. It consists of approximately 435 acres of watershed, 2.2 linear stream miles, and stormwater management facilities. Four stream reaches were targeted for restoration and four stormwater facility retrofits were planned in the drainage area (Harford County DPW 2008). Restoration and retrofit activities began in 2012 and continued through the current monitoring period (Table 2-1). Pre-construction data will be used to assess performance of a portion of the stream restoration and stormwater BMP retrofit projects. Construction on the two most recent projects (Lower Wheel Creek restoration and Pond E) began in 2016 and were completed in early 2017.

Table 2-1. Timeline of restoration and retrofit projects in Wheel Creek watershed (M. Dobson pers. comm.)

Construction Projects	Start Date	Completion Date
Gardens of Bel Air (Pond A)	September 8, 2012	December 20, 2012
Calverts Walk (UMS-1)	January 14, 2013	April 4, 2013
Festival of Bel Air (Pond C)	May 12, 2015	August 7, 2015
Country Walk 1A (Pond D)	September 21, 2015	December 11, 2015
MMS-5, MB-4, MB-1	December 7, 2015	February 26, 2016
Water Quality Facilities	December 7, 2015	March 18, 2016
Lower Wheel Creek	September 19, 2016	March 2017
Country Walk 1B (Pond E)	December 2016	April 2017

The water chemistry monitoring study design employs comparisons of pre- and post-restoration and retrofit conditions. Three long-term automated water chemistry sampling and flow logging stations were established at Stations WC002, WC003, and WC004 (Figure 2-1). Station WC004 is located on an unnamed tributary to Wheel Creek immediately downstream of the stormwater retrofit at Festival Shopping Center (Point C). Stations WC003 and WC004 bracket completed stormwater retrofits at Pond D and Pond E along an unnamed tributary. Station WC002 is located on the mainstem and water chemistry data collected there will provide an overall assessment of the benefits of retrofit and restoration projects in upstream tributaries (Figure 2-2). Baseflow monitoring took place at three stations along the Wheel Creek main stem and tributaries (WC002, WC003, and WC004). Nutrient synoptic sampling took place at eight indicator stations in Wheel Creek Watershed (Figure 2-2) and eight control stations in a nearby reference watershed, a tributary to Winters Run (Figure 2-3).

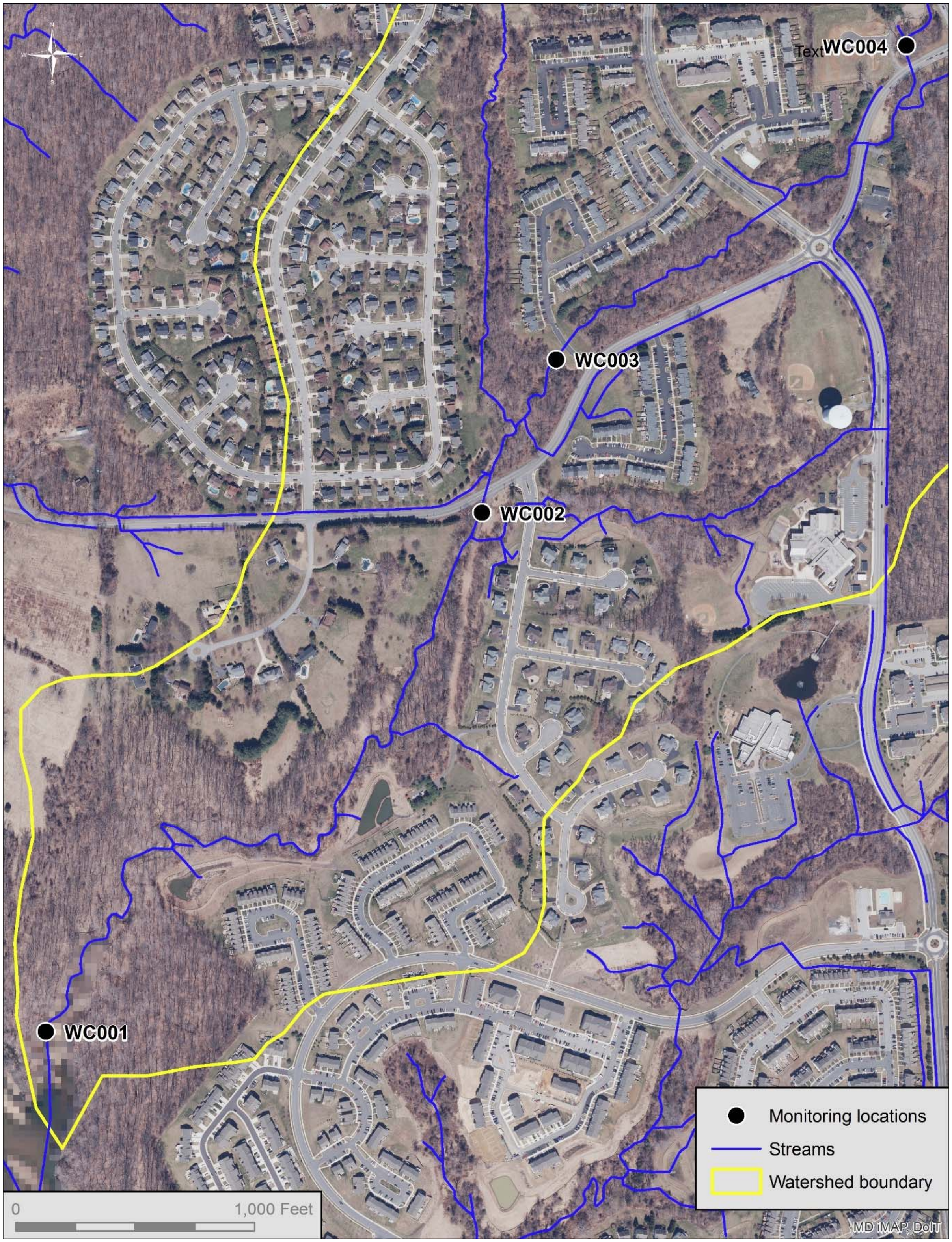

Figure 2-1. Wheel Creek Watershed long-term water chemistry monitoring stations

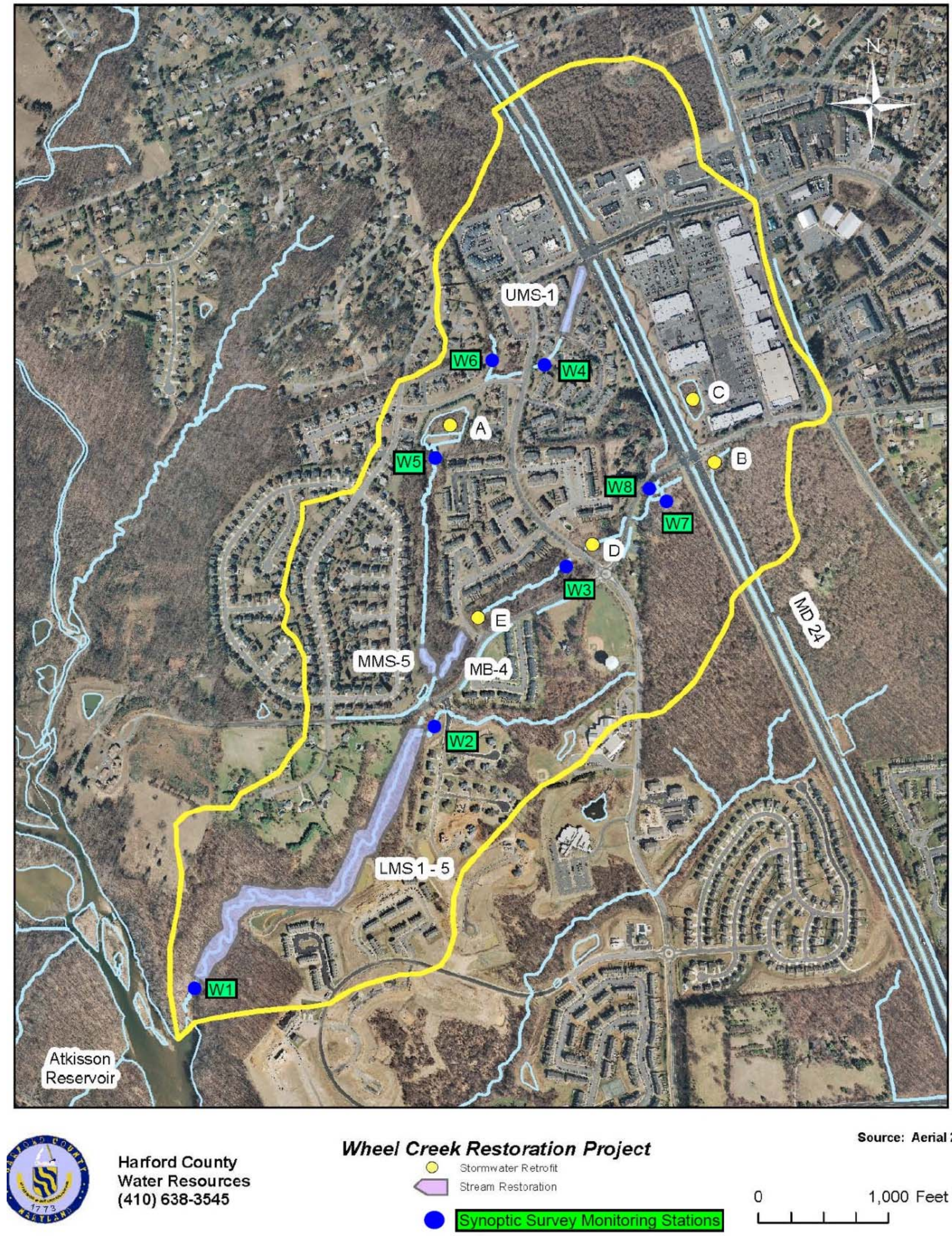

Figure 2-2. Nutrient synoptic sampling stations, stream restoration sites, and stormwater retrofit sites in Wheel Creek watershed

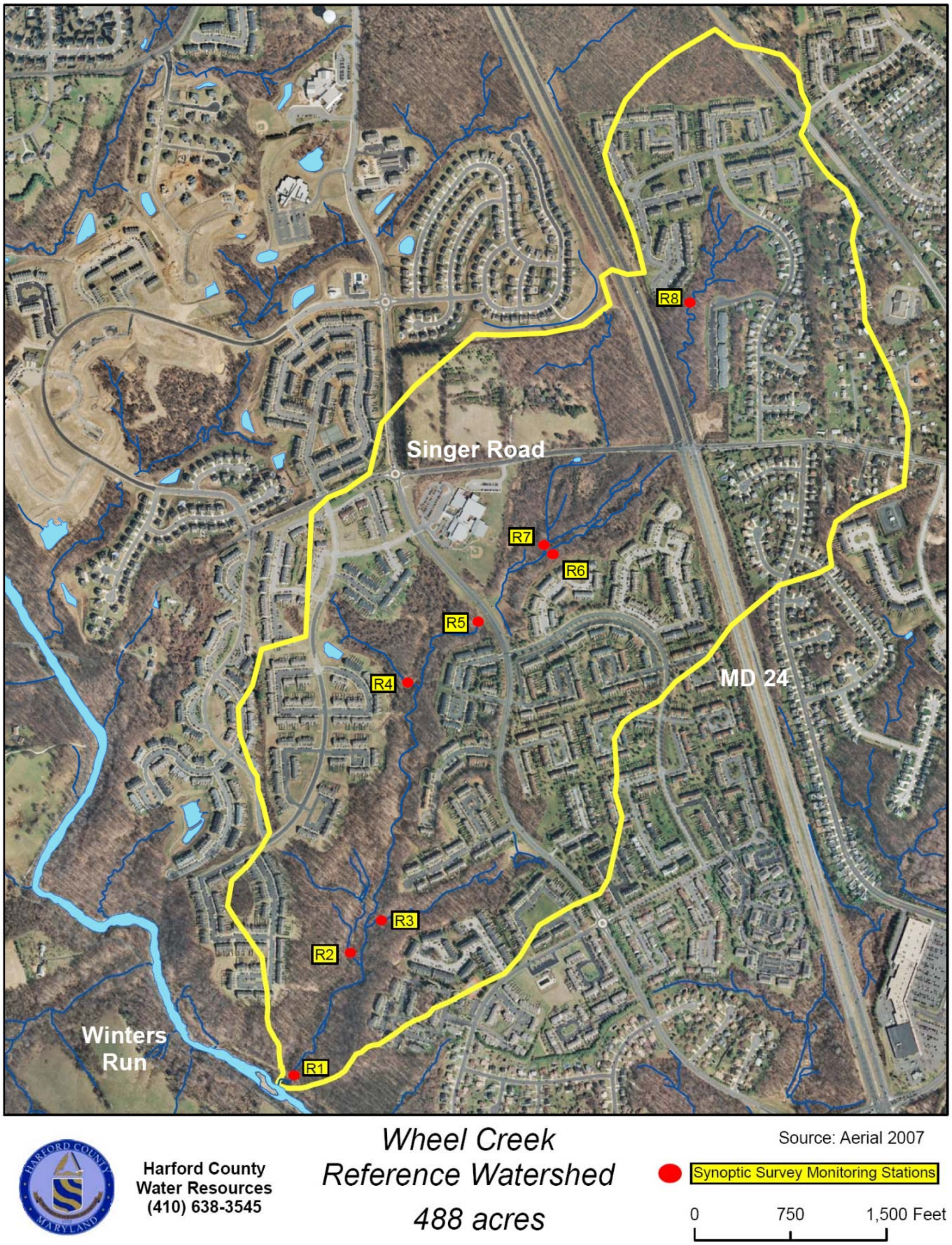

Figure 2-3. Reference synoptic sampling stations

3.0 METHODS AND MATERIALS

3.1 STORMFLOW MONITORING

Fixed, automated stormflow monitoring and long-term flow logging stations were situated at the following locations:

- WC002 – Wheel Creek mainstem at Wheel Road
- WC003 – Wheel Creek Tributary at Cinnabar Lane
- WC004 – Wheel Creek Tributary off Wheel Court

Stormflow samples were collected by Versar staff using American Sigma 900Max samplers coupled to area-velocity probes at Stations WC002 and WC003, and working in conjunction with a bubbler flowmeter at Station WC004. Automated sampling equipment was installed in September 2010 at Station WC002 and Station WC003 and mid-October 2010 at Station WC004. During Storms, area-velocity sensors were secured at the downstream end of culverts at Station WC002 and Station WC003 while the bubbler tube at Station WC004 was secured instream. At Station WC004, an ISCO 4230 bubbler flowmeter was used to record level data. Automated samplers contained 24, one-liter polypropylene bottles and were programmed to start at a specific time (based on the storm forecast) by field staff to sample the rising, peak, and falling limbs of the storm on a time-paced basis. Separate composite samples were created on a discharge volume-proportional basis to represent the rising, peak, and falling limbs of the stream hydrograph.

Nine events were monitored between July 1, 2016 and June 30, 2017 (Table 3-1). Event rainfall duration was calculated from the first to the last measurable amounts of rain which trigger the tipping mechanism within each rain gauge. Antecedent dry time was calculated by determining the time interval between the initiation of rainfall for the monitored event and the cessation of rainfall for the prior event. Qualifying storm events required a minimum of 24 hours where there has been less than 0.03 inches total accumulated rainfall.

Flow rate during monitored storm events was determined using the area-velocity probes at Stations WC002 and WC003 and by rating curve at Station WC004.

The rating curve at Station WC004 was prepared using directly-measured velocities, over a range of stages, along a stream channel cross-section (Appendix B). Versar field staff measured velocity and channel depth using a Marsh-McBirney Flowmate 2000 flowmeter, with sensor attached to a graduated wading rod (Jones and Hage 2011). Automated storm sampling procedures are described in fuller detail in the project's Quality Assurance and Quality Control Document (Jones and Hage 2011).

Stream water samples were tested for the analytes listed in Table 3-2. Since May 2013, samples were tested for an expanded suite of analytes that included: turbidity, chloride, dissolved total Kjeldahl nitrogen (TKN), dissolved nitrate plus nitrite, and dissolved total phosphorus. Analytes with multiple detection limits are presented as a range in Table 3-2.

Table 3-1. Statistics for monitored storms, 2016-17

Date	Rainfall Total (in.)	Rainfall Duration (hr.)	Antecedent Dry Time (hr.)
17-Aug-16	0.46	5.66	46.23
19-Sept-16	0.75	9.0	426.33
29-Nov-16	0.96	13.33	225.42
6-Dec-16	0.79	14.25	31.75
28-Feb-17	0.18	10.0	72.42
18-Mar-17*	N.C.	N.C.	N.C.
31-Mar-17	1.49	18.0	58.33
4-May-17	1.31	13.75	205.42
19-Jun-17	0.95	6.17	296.5

Rainfall recorded by primary onsite rain gauge at Station WC002
*snow melt event, N.C.= Not Collected

Table 3-2. Parameters, methods, detection limits, and water quality criteria for Wheel Creek monitoring and nutrient synoptic sampling

Parameter	Analytical Method	Reporting Limit (mg/L)	Method Detection Limit (mg/L)	Wheel Creek Storm and Baseflow	Nutrient Synoptic Sampling	MD Freshwater Criteria[a] Acute (µg/l)	MD Freshwater Criteria[a] Chronic (µg/l)	EPA Recommended Ambient Water Quality Criteria[b] (mg/L)
BOD-5	SM 5210 B	2-6	2-6	√				
Nitrate	EPA 300.0	0.05-0.5	0.0366-0.48	√				
Nitrate + Nitrite	EPA 300.0	0.05-0.5	0.03-0.424	√	√			0.69 (Total N)[c]
Total Kjeldahl Nitrogen	EPA 351.2	0.2	0.102	√				
Orthophosphate	SM 4500-P E	0.05	0.01	√	√			
Total Suspended Solids	SM 2540D	4-7	4-7	√				
Copper	EPA 200.7	0.01	0.004	√		13	9	
Lead	EPA 200.7 EPA 200.8	0.015	0.0062	√		65	2.5	
Zinc	EPA 200.7	0.001	0.0001	√		120	120	
Chloride[d]	EPA 300.0	1-10	0.0657-1.17	√				860 (acute) 230 (chronic)
Ammonia	SM 4500 NH3G	0.02	0.0054-0.0065	√				
Total Phosphorus	EPA 365.4	0.2	0.056-0.13	√				0.03656
Hardness	SM234B	0.05	0.0186	√				
Turbidity	SM2130B	0.2	0.038-0.06	√				
Dissolved Nitrate + Nitrite	EPA 300.0	0.1	0.0297-0.032	√				
Dissolved Total Kjeldahl Nitrogen	EPA 351.2	0.05-0.5	0.03-0.424	√				
Dissolved Total Phosphorus	EPA 365.4	0.2	0.102	√				
Total Petroleum Hydrocarbons	EPA 1664B	0.05	0.0186	√				
E. coli (reported as MPN/100 ml)	SM 9223B	5	1.4	√				

(a) Values from COMAR 26.08.02.03-2 (undated).
(b) U.S. EPA 2000. Recommended criteria are derived from the 25th percentile of concentrations in all streams in the ecoregion.
(c) Total nitrogen concentration is the sum of total Kjeldahl nitrogen and combined nitrate plus nitrite.
(d) U.S. EPA 1988. Ambient Water Quality Criteria for Chloride.

Storm event mean concentrations (EMCs) were calculated individually for each storm by obtaining the concentration of each pollutant, weighted according to limb discharge volume. Limb discharges were determined by plotting the portion of the storm hydrograph represented by the composite sample and integrating under the curve using Flowlink software. For TPH and *E. coli*, which were collected by grab during irregular occasions during stormflow, a simple average concentration without flow weighting was calculated ("greater than" *E. coli* results were set to the numerical result).

Estimated pollutant loading values for each storm were determined by multiplying the storm EMCs by the total storm discharge in cubic feet. Total storm discharge was determined by plotting the storm hydrograph and integrating under the curve using Flowlink software.

3.2 BASEFLOW MONITORING

Baseflow monitoring was completed monthly by DPW staff. Grab samples were collected at the locations listed below.

- WC002 – Wheel Creek mainstem at Wheel Road
- WC003 – Wheel Creek Tributary at Cinnabar Lane
- WC004 – Wheel Creek Tributary off Wheel Court

3.3 NUTRIENT SYNOPTIC SAMPLING

Nutrient synoptic sampling was conducted by DPW staff during spring 2017 throughout the Wheel Creek Watershed and the reference watershed for orthophosphate and combined nitrate plus nitrite. The reference watershed was selected because it is similar in size to, is in close proximity to, contained similar soils as, and contained a similar level of development to Wheel Creek Watershed, but in which no restoration is planned. Sampling was conducted by grab during baseflow conditions. Instantaneous flow rate measurements were determined by DPW staff using a Marsh-McBirney Flowmate 2000 and a wading rod. Daily baseflow discharge rates (in CF/day) and nutrient export yields (in kg/ha/day) were computed and compared with literature values to categorize nutrient levels at the stations as baseline, moderate, high, or excessive (Table 3-3).

Table 3-3. Nutrient synoptic sampling nutrient ranges and rating (Frink 1991)

Rating	$NO_2 + NO_3$ Concentration (mg/L)	$NO_2 + NO_3$ Yield (kg/ha/day)	Orthophosphate Concentration (mg/L)	Orthophosphate Yield (kg/ha/day)
Baseline	< 1	< 0.01	< 0.005	< 0.0005
Moderate	1 to 3	0.01 to 0.02	0.005 to 0.01	0.0005 to 0.001
High	3 to 5	0.02 to 0.03	0.01 to 0.015	0.001 to 0.002
Excessive	> 5	> 0.03	> 0.015	> 0.002

3.4 LONG-TERM FLOW RATE LOGGING

Long-term flow rate logging stations were located at WC002, WC003, and WC004 described above. Maryland Department of Natural Resources (DNR) installed Solinst flow loggers in 2012 and maintained them through June 2016, at which point Versar assumed responsibility for monitoring and maintenance. Versar conducted monthly site inspections, logger downloads, and baseflow discharge measurements between July 2016 and June 2017. Storm discharge measurements were also collected whenever possible to verify the rating curve at each station.

During the winter months, the Solinst flow loggers were removed from service on several occasions to prevent damage to the sensors due to icing. During these periods, ISCO flowmeters were installed to capture level data while the Solinst loggers were offline. At Station WC003, ongoing construction necessitated the removal of the Solinst logger from December 15, 2016 to April 21, 2017 to prevent damage. Construction activity included pumping and diverting flow just upstream of the flow logging station, which precluded collection of an accurate flow record.

Complete flow series for each station were compiled from the Solinst and ISCO logger data. Staff performed quality control on the level time series to remove any anomalous data (e.g., resulting from manipulation during Solinst data offloads). To compensate for logger drift, levels were corrected to reflect observed staff gauge readings, and a LOESS curve of these corrections was applied to the time series at each station. A rating curve was established at each of the three logging stations to convert each logger's level data to flow rate (Appendix B).

3.5 RAINFALL LOGGING

Rainfall was recorded by an Onset HOBO electronic, tipping-bucket rain gauge situated in an open area near Station WC002. The gauge was downloaded and maintained by Versar field staff and is the primary gauge used for storm event rainfall totals. Daily rainfall recorded by the gauge is presented in Appendix C. Rainfall records from USGS' Atkisson Reservoir gauge (0.8 miles away to the SW), the secondary rainfall recorder, were used to supplement the onsite data in cases where onsite gauge data were unavailable due to power interruptions or mechanical failures.

3.6 DETERMINATION OF STORM EVENT POLLUTANT LOADS

Pollutant loads were determined by multiplying the pollutant event mean concentration (a stream flow volume-weighted mean of analytical results from laboratory analysis) by the total storm discharge at the point of sample collection. Stream discharge volume for a specific time interval (for a specific limb or the total event) is determined by integrating under the flow rate hydrograph over the time period of interest. The pollutant event mean concentration (EMC) for a given storm is determined by:

$$\text{EMC} = \frac{\sum_{i=1}^{3} C_i V_i}{\sum_{i=1}^{3} V_i}$$

Where:

EMC = Event Mean Concentration of specific pollutant
i = Numerical representation of storm limb (1=rising, 2=peak, 3=falling)
C_i = Pollutant concentration at limb i
V_i = Corresponding discharge represented by composite sample collected for limb i.

The average pollutant EMC for the monitoring year is an arithmetic mean of individual storm EMCs.

Pollutant load for a given storm is calculated by:

$$L = (k_1 / k_2) \times (\text{EMC} \times V_T)$$

Where:

L = estimated load in pounds
k_1 = conversion factor 28.317 liters per cubic foot
k_2 = conversion factor of 453592.4 milligrams per pound
V_T = estimated total storm runoff in stream in ft^3

The average pollutant load for the monitoring year is an arithmetic mean of individual storm loads.

3.7 DETERMINATION OF AVERAGE ANNUAL AND SEASONAL EMC AND TOTAL ANNUAL AND SEASONAL LOAD

Average annual storm EMCs for each pollutant at each station were determined by obtaining the arithmetic mean of individual storm EMC data for a given year. Average annual baseflow Mean Concentrations (MCs) were developed by calculating the arithmetic mean of concentration data. Average seasonal EMCs and MCs were obtained by using the same method, except on a seasonal basis. Below-reportable detection limit results were set to zero when determining average EMCs and determining baseflow MCs.

Total annual load was determined by (a) multiplying all stormflow volume in a given year at a given station by the corresponding average annual EMC for each pollutant, (b) multiplying all baseflow volume in the same year by the corresponding average annual MC, and (c) summing the result.

3.8 SUSPENDED SEDIMENT TRANSPORT MONITORING

Suspended sediment transport was monitored at all three Wheel Creek storm monitoring stations, WC002, WC003, and WC004 (Figure 2-1). Sediment samples were collected in conjunction with wet weather samples, for a total of nine events at Stations WC002 & WC004 and six events at Station WC003.

From July 2016 through June 2017, suspended sediment was monitored during nine wet weather sampling events using a modified siphon sampler (Diehl 2008) outfitted with a HOBO® U20 depth logger for continuous stage recording. The modified siphon sampler was developed by USGS to sample shallow water at closely spaced vertical intervals, enabling samples to be collected passively at multiple stages of the rising limb of the hydrograph. Each sampler included six 1000-mL sample containers oriented horizontally with an intake tube and an air vent, which allowed sample collection at up to six different stages. Samples collected were analyzed individually for suspended sediments following a standard method for total suspended solids (SM2540D; APHA, 1999), with filtration of the full 1000-mL sample.

Since the sampler devices could not be deployed in the same location as the gauge recorders without causing interference, discharge corresponding to each sample was determined using depth data obtained from the HOBO® loggers. The loggers were set to record pressure and temperature data at 1-minute intervals for the full duration of their deployment. The logger data were then post-processed using HOBOware Pro 2.7.3 software, to correct for changes in barometric pressure. The resulting data were used to determine the approximate time that each sample bottle was filled, and the corresponding discharge from the time of sample collection was obtained from the storm event flow rate graphs for each station. The relationship between discharge and suspended sediment concentration was then plotted to create a sediment-transport curve (Glysson 1987) for each station.

4.0 RESULTS AND DISCUSSION

Results of stormflow, baseflow, and synoptic sampling performed from July 1, 2016 through June 30, 2017 are presented and discussed in this section. The individual sample analytical data are compiled into tables while annual average concentrations and loadings are presented in tabular and graphical form.

4.1 STORMFLOW CONCENTRATION RESULTS

Analytical results for storm samples collected at each of the three stations are presented in Table 4-1. Total nitrogen results were greater than the EPA recommended reference value of 0.69 mg/L (U.S. EPA 2000) in 98.6% of the samples in this monitoring period compared to 93.5% in the previous period of monitoring. Of the samples in which total phosphorus was detected, 86.6% of the results were greater than the EPA recommended reference value of 0.03656 mg/L. Orthophosphate was not detected in any stormflow samples collected. Ammonia results were below the detection limit in 79.7% of stormflow samples collected at all stations during the year. Analyses for dissolved parameters were not performed for the June 2016 storm.

As was the case in the six prior monitoring periods, zinc was detected in all stormflow samples. Zinc concentrations were greater than MDE's acute criterion for surface water in 4.3% of the samples (Table 3-2).[1] Lead concentrations were above the detection limit in 62.3% of the samples, of which 100% were below the MDE acute criterion. Note that Eurofins QC Labs changed the analytical method for lead in December 2016, resulting in a higher overall detection rate. Copper concentrations were above the detection limit in 97.1% of samples; however, only 18.8% were greater than the MDE acute criterion for surface water.

E. coli concentrations were equal to or above the maximum reportable result (2,420 MPN/100ml) in 50% of stormflow grab samples. TPH was detected in one of the 21 stormflow grab samples collected at the monitoring stations, however it was below the reporting limit and was flagged for accuracy concerns.

The rising limb results indicated higher average concentrations than the peak or falling limbs at all three stations for the following parameters: biochemical oxygen demand (BOD), nitrate, nitrate plus nitrite, orthophosphate, TKN, total suspended solids (TSS), copper, lead, zinc, hardness, turbidity, and chloride. The March 20th event results showed significantly higher chloride concentrations (> 300 mg/L) at Stations WC002 and WC004 than during the remainder of the monitoring period. BOD values were generally lower in winter months for all sites than at other times of the year.

[1] The zinc, lead, and copper criteria are based on the dissolved form, while the laboratory analytical results are for total metal concentration. Comparisons to surface water criteria are for discussion purposes only and do not imply violations of surface water standards.

Storm sample analytical results for filtered samples are presented in Table 4-2. TKN was detected in 98.6% of filtered samples while nitrate plus nitrite was detected in 100% of filtered samples taken at all three stations. Total nitrogen results were comparable to unfiltered samples in that they were greater than the EPA recommended reference value of 0.69 mg/L in 95.7% of samples. Phosphorus was detected in 13.0% of filtered samples at all three stations. When detected, phosphorus was below the EPA recommended reference value of 0.03656 mg/L in all samples.

Table 4-1. Stormflow water chemistry results, July 2016 – June 2017. All concentrations are in units of mg/L unless indicated.

Storm Date	Limb	Dis-charge (cf)	5-Day BOD	Ammo-nia	Nitrate	Nitrate + Nitrite	Ortho-phos-phate	TKN	Total P	TSS	Copper (µg/l)	Lead (µg/l)	Zinc (µg/l)	TPH	*E. coli* (MPN/ 100 ml)	Total Nitro-gen	Hard-ness	Chlor-ide	Turbid ity (NTU)
Station WC002																			
8/19/2016	Rising	1,591	7	0.194	1.0	1.0	< 0.05	0.886	0.111	41	5.4	< 15	19.9	N.C.	N.C.	1.886	79	64.9	22
8/19/2016	Peak	22,991	6	0.178	0.663	0.663	< 0.05	0.47	0.0732	15.6	< 10	< 15	12	N.C.	N.C.	1.133	38	26.7	12
8/19/2016	Falling	10,306	4	< 0.2	0.683	1.02	< 0.05	0.455	0.0536	5.2	4.7	< 15	8.4	< 5	1990	1.475	43	30.1	7
9/20/2016	Rising	2,959	9	< 0.2	1.82	1.82	< 0.05	0.739	0.141	54.2	6.4	< 15	34.2	2.1	> 2420	2.559	115	97	38
9/20/2016	Peak	54,910	15	< 0.2	0.983	0.983	< 0.05	1.13	0.2	57	9.9	< 15	32	N.C.	N.C.	2.113	45	35.8	32
9/20/2016	Falling	7,858	10	< 0.2	0.935	0.935	< 0.05	0.554	0.0622	7.6	4.8	< 15	8.9	N.C.	N.C.	1.489	49	33.6	8
12/1/2016	Rising	3,658	18	< 0.2	1.79	1.79	< 0.05	1.13	0.123	50.8	8.2	< 15	42.4	< 5	308	2.92	149	121	25
12/1/2016	Peak	55,282	17	< 0.2	0.712	0.712	< 0.05	1.32	0.18	48	10.4	< 15	40.1	N.C.	N.C.	2.032	45	36.5	26
12/1/2016	Falling	19,578	11	< 0.2	0.92	0.92	< 0.05	0.65	0.0432	5.2	26.3	< 15	17.9	N.C.	N.C.	1.57	44	37.8	7
12/7/2016	Rising	1,941	3	< 0.2	1.07	1.07	< 0.05	0.32	0.0217	17.6	< 10	0.5	14.8	< 5	138	1.39	105	74.2	13
12/7/2016	Peak	65,187	< 2	< 0.2	0.224	0.224	< 0.05	0.573	0.0789	20	5.7	0.78	17.4	N.C.	N.C.	0.797	21	10.6	22
12/7/2016	Falling	16,830	< 2	< 0.2	0.38	0.38	< 0.05	0.483	0.0376	4.4	5.4	0.57	14.5	N.C.	N.C.	0.863	35	21.9	14
3/20/2017	Rising	2,874	6	< 0.2	0.895	0.895	< 0.05	0.285	< 0.05	4	5.1	0.25	21.3	N.C.	N.C.	1.18	115	439	7
3/20/2017	Peak	7,510	4	< 0.2	0.567	0.567	< 0.05	0.426	0.0328	4.4	4.6	0.38	18.7	N.C.	N.C.	0.993	85	403	12
3/20/2017	Falling	7,409	5	< 0.2	0.598	0.598	< 0.05	0.454	0.0332	4	6.8	0.36	22	N.C.	N.C.	1.052	80	333	11
4/2/2017	Rising	19,607	< 2	0.178	0.83	0.83	< 0.05	0.735	0.0458	19.2	8.2	0.73	23.9	N.C.	N.C.	1.565	75	151	16
4/2/2017	Peak	297,123	6	< 0.2	0.348	0.348	< 0.05	1.1	0.185	106	10.1	2.2	35.6	< 5	> 2420	1.448	30	51.4	64
4/2/2017	Falling	18,851	5	< 0.2	0.835	0.835	< 0.05	0.668	0.0478	7.2	7.3	0.63	18.7	N.C.	N.C.	1.503	58	84.3	16
5/7/2017	Rising	23,067	17	< 0.2	1.08	1.29	< 0.05	1.61	0.258	125	12.4	3	66.5	< 5	2420	2.9	93	82.1	56
5/7/2017	Peak	169,329	11	< 0.2	0.422	0.531	< 0.05	0.869	0.102	55.6	10.2	1.1	24.9	N.C.	N.C.	1.4	29	20.1	21
5/7/2017	Falling	34,221	10	< 0.2	0.465	0.589	< 0.05	0.781	0.0862	17.6	9.5	0.77	20.6	N.C.	N.C.	1.37	34	24.7	17
6/20/2017	Rising	68,499	22	0.0694	0.621	0.712	< 0.05	2.76	0.492	229	22.6	7.7	114	N.C.	N.C.	3.472	57	41	90
6/20/2017	Peak	73,108	16	< 0.2	0.45	0.526	< 0.05	1.14	0.175	50	10.5	1.7	31.6	N.C.	N.C.	1.666	31	21.1	26
6/20/2017	Falling	23,405	9	0.0709	0.447	0.527	< 0.05	0.924	0.104	18	6.7	0.75	19.4	< 5	N.C.	1.451	37	24.8	11

Table 4-1. (Continued)

Storm Date	Limb	Dis-charge (cf)	5-Day BOD	Ammo-nia	Nitrate	Nitrate + Nitrite	Ortho-phos-phate	TKN	Total P	TSS	Copper (µg/l)	Lead (µg/l)	Zinc (µg/l)	TPH	*E. coli* (MPN/ 100 ml)	Total Nitro-gen	Hard-ness	Chlor-ide	Turbid ity (NTU)
Station WC003																			
8/19/2016	Rising	3,167	7	< 0.2	0.758	0.758	< 0.05	0.786	0.127	72.5	12.4	< 15	30.3	N.C.	N.C.	1.544	54	45.1	28
8/19/2016	Peak	11,336	7	< 0.2	0.572	0.572	< 0.05	0.631	0.0773	27.2	9.5	< 15	18.2	N.C.	N.C.	1.203	38	30.5	12
8/19/2016	Falling	4,908	5	< 0.2	0.601	0.601	< 0.05	0.286	0.0493	16.8	5.3	< 15	12.7	< 5	1120	0.887	47	37	8
9/20/2016	Rising	3,021	17	< 0.2	1.53	1.53	< 0.05	1.86	0.426	210	16.6	< 15	91.6	< 5	> 2420	3.39	161	150	135
9/20/2016	Peak	18,943	11	< 0.2	0.843	0.843	< 0.05	0.744	0.106	35.2	10.1	< 15	30.6	N.C.	N.C.	1.587	41	34.1	22
9/20/2016	Falling	7,136	7	< 0.2	0.932	0.932	< 0.05	0.699	0.0681	14.4	6	< 15	16.5	N.C.	N.C.	1.631	53	34.9	7
12/1/2016	Rising	5,950	4	< 0.2	2.56	2.56	< 0.05	2.26	0.453	210	22.5	8.2	141	< 5	2420	4.82	147	150	134
12/1/2016	Peak	19,240	9	< 0.2	0.958	0.958	< 0.05	1.16	0.122	39.6	11.4	< 15	38.2	N.C.	N.C.	2.118	48	42.2	26
12/1/2016	Falling	9,182	18	< 0.2	0.885	0.885	< 0.05	0.778	0.045	12	10.4	< 15	24.6	N.C.	N.C.	1.663	46	39.2	10
12/7/2016	Rising	7,215	3.22	< 0.2	0.432	0.432	< 0.05	0.58	0.0622	34.4	5.2	1.1	24.3	< 5	49.6	1.012	70	55.9	22
12/7/2016	Peak	20,111	2.4	< 0.2	0.311	0.311	< 0.05	0.536	1.24	7.2	6.7	0.84	16.7	N.C.	N.C.	0.847	25	16.3	20
12/7/2016	Falling	18,126	2.4	< 0.2	0.314	0.314	< 0.05	0.536	0.0403	< 5	5.2	0.59	15.5	N.C.	N.C.	0.85	33	22.8	16
5/7/2017	Rising	12,350	15	< 0.2	0.742	0.944	< 0.05	1.89	0.315	184	18.4	6.2	99.6	< 5	> 2420	2.834	103	91.9	65
5/7/2017	Peak	48,829	19	0.15	0.269	0.391	< 0.05	0.967	0.119	45.6	11.6	1.6	29.6	N.C.	N.C.	1.358	42	32.9	20
5/7/2017	Falling	17,871	11	0.226	0.292	0.418	< 0.05	0.649	0.0447	12.8	6.9	0.61	13.9	N.C.	N.C.	1.067	42	38.6	6
6/20/2017	Rising	23,669	19	0.121	0.505	0.597	< 0.05	2.05	0.357	219	34.3	8.9	127	N.C.	N.C.	2.647	68	49.9	88
6/20/2017	Peak	21,436	15	0.0808	0.413	0.497	< 0.05	1.26	0.165	40.4	12.4	1.9	35.5	N.C.	N.C.	1.757	44	34.4	20
6/20/2017	Falling	4,611	13	< 0.2	0.334	0.409	< 0.05	0.677	0.043	7.2	4.6	0.44	13.7	< 5	N.C.	1.086	52	37.2	5
Station WC004																			
8/19/2016	Rising	1,019	8	< 0.2	0.579	0.579	< 0.05	1.05	0.151	59.2	21.2	< 15	47.7	N.C.	N.C.	1.629	33	25.3	15
8/19/2016	Peak	6,729	5	< 0.2	0.506	0.506	< 0.05	0.606	0.0773	11.2	10.3	< 15	19.3	N.C.	N.C.	1.112	27	18.8	5
8/19/2016	Falling	2,498	< 2	< 0.2	0.613	0.613	< 0.05	0.295	0.0409	4	5.5	< 15	13.8	< 5	613	0.908	33	21.9	4
9/20/2016	Rising	7,561	5	< 0.2	3.75	3.75	< 0.05	0.5	0.0856	24.4	6.2	< 15	33.8	< 5	>2420	4.25	182	193	8
9/20/2016	Peak	18,147	7	< 0.2	0.858	0.858	< 0.05	0.779	0.0902	11.4	7.3	< 15	20.3	N.C.	N.C.	1.637	27	18.2	6
9/20/2016	Falling	9,576	10	< 0.2	0.639	0.639	< 0.05	0.847	0.084	6	7.1	< 15	24.3	N.C.	N.C.	1.486	35	20.9	6
12/1/2016	Rising	9,470	7	< 0.2	1.07	1.07	< 0.05	1.04	0.157	68.4	15.7	< 15	56.3	< 5	>2420	2.11	49	36.7	23

Table 4-1. (Continued)

Storm Date	Limb	Dis-charge (cf)	5-Day BOD	Ammo-nia	Nitrate	Nitrate + Nitrite	Ortho-phos-phate	TKN	Total P	TSS	Copper (µg/l)	Lead (µg/l)	Zinc (µg/l)	TPH	*E. coli* (MPN/ 100 ml)	Total Nitro-gen	Hard-ness	Chlor-ide	Turbidity (NTU)
Station WC004 (Continued)																			
12/1/2016	Peak	29,699	6	< 0.2	0.898	0.898	< 0.05	1.19	0.159	64	17.3	< 15	76.3	N.C.	N.C.	2.088	26	21.9	20
12/1/2016	Falling	8,629	3	< 0.2	0.792	0.792	< 0.05	0.828	0.0344	< 4	8.6	< 15	27	N.C.	N.C.	1.62	24	20.2	6
12/7/2016	Rising	8,923	3.34	< 0.2	0.266	0.266	< 0.05	1.1	0.142	64.8	12	3.5	63	< 5	27.2	1.366	27	17.1	23
12/7/2016	Peak	21,363	< 2	< 0.2	0.459	0.459	< 0.05	0.534	0.0378	21.5	6	0.77	23.8	N.C.	N.C.	0.993	16	6.99	11
12/7/2016	Falling	8,494	< 2	< 0.2	0.335	0.335	< 0.05	0.325	< 0.05	< 4	5	0.56	21.6	N.C.	N.C.	0.66	23	12.1	6
3/1/2017	Rising	418	5	< 0.2	2.47	2.47	< 0.05	0.544	0.0193	4.4	7.2	0.51	32.8	< 5	111	3.014	195	267	3
3/1/2017	Peak	1,991	3	< 0.2	0.545	0.715	< 0.05	0.773	0.0455	5.6	11	0.76	27.7	N.C.	N.C.	1.488	39	90.1	7
3/1/2017	Falling	1,434	< 2	< 0.2	0.667	0.838	< 0.05	0.661	0.033	< 4	8.9	0.63	24.4	N.C.	N.C.	1.499	43	97.3	5
3/20/2017	Rising	1,008	< 2	< 0.2	0.512	0.512	< 0.05	0.722	0.0761	89.6	9.2	3.4	31.4	N.C.	N.C.	1.234	60	424	30
3/20/2017	Peak	1,238	< 2	< 0.2	0.447	0.447	< 0.05	0.403	0.0189	< 4	6.9	0.78	23	N.C.	N.C.	0.85	54	390	8
3/20/2017	Falling	946	< 2	< 0.2	0.532	0.532	< 0.05	0.506	0.0279	< 4	5.7	0.75	26.7	N.C.	N.C.	1.038	60	369	7
4/2/2017	Rising	12,484	3	< 0.2	0.397	0.397	< 0.05	0.985	0.0748	43.2	12.5	1.7	46.5	N.C.	N.C.	1.382	35	215	19
4/2/2017	Peak	28,113	5	< 0.2	0.225	0.225	< 0.05	0.563	0.0683	45.4	10.2	1.4	34.2	< 5	214	0.788	24	96.4	18
4/2/2017	Falling	13,315	2	< 0.2	0.343	0.343	< 0.05	0.469	0.0283	9.2	5.9	0.73	43.8	N.C.	N.C.	0.812	35	118	10
5/7/2017	Rising	8,427	15	0.354	0.635	0.786	< 0.05	1.86	0.242	107	17.1	3.8	75.5	< 5	>2420	2.646	37	35.3	44
5/7/2017	Peak	26,571	12	0.145	0.428	0.533	< 0.05	1.26	0.173	98	16.1	3.5	59.2	N.C.	N.C.	1.793	19	15.3	38
5/7/2017	Falling	11,302	13	0.335	0.459	0.586	< 0.05	0.861	0.0705	30	10	1.5	31.2	N.C.	N.C.	1.447	27	25.3	18
6/20/2017	Rising	10,792	12	< 0.2	0.351	0.417	< 0.05	2.16	0.428	142	40.9	14.3	141	N.C.	N.C.	2.577	35	20.6	50
6/20/2017	Peak	11,435	11	0.131	0.374	0.442	< 0.05	1.23	0.176	65.6	19.5	3.8	64.3	N.C.	N.C.	1.672	30	19.6	18
6/20/2017	Falling	6,172	8	0.0688	0.272	0.334	< 0.05	0.901	0.0741	16.4	8.8	1.2	29.8	< 5	N.C.	1.235	28	18.6	28

N.C. = Sample Not Collected

Table 4-2. Stormflow filtered water chemistry results, July 2016 – June 2017. All concentrations are in units of mg/L unless indicated.

Station		WC002				WC003				WC004			
			Dissolved				Dissolved				Dissolved		
Storm Date	Limb	Dis-charge (cf)	Nitrate + Nitrite	TKN	Total P	Dis-charge (cf)	Nitrate + Nitrite	TKN	Total P	Dis-charge (cf)	Nitrate + Nitrite	TKN	Total P
8/19/2016	Rising	1,591	1.02	0.522	< 0.05	3,167	0.814	0.222	< 0.05	1,019	0.635	0.406	0.0216
8/19/2016	Peak	22,991	0.708	0.264	< 0.05	11,336	0.585	0.376	< 0.05	6,729	0.579	0.259	0.02
8/19/2016	Falling	10,306	0.712	0.426	< 0.05	4,908	0.649	< 0.2	< 0.05	2,498	0.643	0.242	0.0358
9/20/2016	Rising	2,959	1.54	0.149	< 0.05	3,021	1.97	0.42	< 0.05	7561	3.96	0.45	< 0.05
9/20/2016	Peak	54,910	1.61	0.578	< 0.05	18,943	1.61	0.346	< 0.05	18,147	0.692	0.429	< 0.05
9/20/2016	Falling	7,858	0.863	0.332	< 0.05	7136	1.17	0.293	< 0.05	9576	0.578	0.513	< 0.05
12/1/2016	Rising	3,658	1.87	0.478	< 0.05	5,950	1.52	0.506	< 0.05	9,470	1.17	0.447	< 0.05
12/1/2016	Peak	55,282	0.805	0.546	< 0.05	19,240	1.03	0.492	< 0.05	29,699	0.844	0.506	< 0.05
12/1/2016	Falling	19,578	1.06	0.524	< 0.05	9,182	0.978	0.586	< 0.05	8,629	0.867	0.484	< 0.05
12/7/2016	Rising	1,941	1.15	0.322	< 0.05	7215.48	0.488	0.496	< 0.05	8923.18	0.311	0.542	< 0.05
12/7/2016	Peak	65,187	0.305	0.47	< 0.05	20,111	0.41	0.466	< 0.05	21,363	0.507	0.387	< 0.05
12/7/2016	Falling	16,830	0.436	0.508	< 0.05	18,126	0.362	0.477	< 0.05	8494.09	0.38	0.301	< 0.05
3/1/2017	Rising	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	418	2.48	0.5	< 0.05
3/1/2017	Peak	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	1,991	0.631	0.549	< 0.05
3/1/2017	Falling	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	1,434	0.823	0.585	< 0.05
3/20/2017	Rising	2,874	0.916	0.314	< 0.05	N.C.	N.C.	N.C.	N.C.	1,008	0.524	0.321	< 0.05
3/20/2017	Peak	7,510	0.579	0.347	< 0.05	N.C.	N.C.	N.C.	N.C.	1,238	0.464	0.367	< 0.05
3/20/2017	Falling	7,409	0.61	0.364	< 0.05	N.C.	N.C.	N.C.	N.C.	946	0.545	0.427	< 0.05
4/2/2017	Rising	19,607	0.81	0.516	< 0.05	N.C.	N.C.	N.C.	N.C.	12,484	0.402	0.536	< 0.05
4/2/2017	Peak	297,123	0.433	0.568	< 0.05	N.C.	N.C.	N.C.	N.C.	28,113	0.248	0.378	< 0.05
4/2/2017	Falling	18,851	0.809	0.461	< 0.05	N.C.	N.C.	N.C.	N.C.	13,315	0.442	0.331	< 0.05

Table 4-2. (Continued)

Station		WC002				WC003				WC004			
			Dissolved				Dissolved				Dissolved		
Storm Date	Limb	Dis-charge (cf)	Nitrate + Nitrite	TKN	Total P	Dis-charge (cf)	Nitrate + Nitrite	TKN	Total P	Dis-charge (cf)	Nitrate + Nitrite	TKN	Total P
5/7/2017	Rising	23,067	1.25	0.468	< 0.05	12,350	0.914	0.505	< 0.05	8,427	0.79	0.683	< 0.05
5/7/2017	Peak	169,329	0.529	0.658	0.0209	48,829	0.38	0.523	< 0.05	26,571	0.541	0.486	0.0232
5/7/2017	Falling	34,221	0.586	0.587	0.0233	17,871	0.403	0.382	< 0.05	11,302	0.612	0.48	< 0.05
6/20/2017	Rising	68,499	0.734	1.29	< 0.05	23,669	0.719	1.11	< 0.05	10,792	0.432	0.921	0.0309
6/20/2017	Peak	73,108	0.532	0.835	0.0243	21,436	0.512	0.884	0.0244	11,435	0.354	0.905	< 0.05
6/20/2017	Falling	23,405	0.53	0.777	< 0.05	4,611	0.42	0.607	< 0.05	6,172	0.34	0.769	< 0.05

4.2 BASEFLOW CONCENTRATION RESULTS

Baseflow sample analytical results are presented in Table 4-3. Under baseflow conditions, concentration values for total phosphorus were below the detection limit in 86.1% of samples. Orthophosphate results were below the detection limit in 100% of baseflow samples. Ammonia was detected in just 2.8% of samples. TSS was detected in 25% of baseflow samples. Total Nitrogen was above the detection limit in all the baseflow samples and all concentration levels were greater than the EPA reference value (0.69 mg/L).

Zinc was detected in all baseflow samples; however, all concentrations were lower than MDE's chronic surface water criterion. Lead was detected in 8.3% of baseflow samples, all of which were lower than MDE's chronic surface water criterion. Copper analytical concentrations were not detected above reporting limits in any baseflow samples.

BOD was detected in 30.6% of samples and mostly at Station WC002. Baseflow concentrations of nitrate and combined nitrate plus nitrite were generally higher at Station WC004 than at the other stations. Zinc concentrations were generally higher at Station WC003 than at the other stations. The highest baseflow turbidity during the monitoring period was observed at Station WC003 in July. In addition, Station WC002 results showed the highest observed turbidity for that site during the same sampling event. Turbidity values at Station WC004 were lower than at the other stations.

Chloride concentrations were elevated from December through May for all stations, but more pronounced for Stations WC003 and WC004. Results from Station WC004 indicated higher chloride concentrations than the other stations. The maximum observed chloride concentrations for Stations WC003 and WC004 occurred during the March sampling event. The lowest chloride concentrations occurred during the September sampling.

Hardness, a characteristic of surface waters, was quantified in all baseflow samples. Concentrations greater than 120 mg/L are considered "Hard", while concentrations exceeding 180 mg/L are considered "Very Hard". Over 90% of baseflow results showed hard water, with 52% in the Hard category and 39% in the Very Hard category. The highest hardness values were found at Station WC004, with 75% of samples classified as Very Hard. There were no baseflow samples collected at any station that were classified as Soft.

E. coli bacteria concentrations were detected in all baseflow samples at all stations, ranging in concentration from 2 to greater than the maximum reporting limit of 2,420 MPN/100ml. The maximum concentration for the study site during the monitoring period occurred during the September sampling event at Station WC002. *E. coli* was also elevated at Station WC003 during the September event. The highest concentration of *E. coli* at Station WC004 occurred in October.

TPH was not detected above the reporting limit in any of the baseflow samples collected from the study area during the monitoring period. However, 25% of TPH sample results were

Table 4-3. Baseflow water chemistry results, 2016-2017. All concentrations are in units of mg/L unless indicated.

Baseflow Date	5-Day BOD	Ammo nia	Nitrate	Nitrate + Nitrite	Ortho-phos-phate	TKN	Total P	TSS	Cop-per (µg/l)	Lead (µg/l)	Zinc (µg/l)	TPH	E. coli (MPN/ 100 ml)	Total Nitro-gen	Hard ness	Chlor-ide	Tur-bidity
Station WC002																	
7/12/2016	< 2	< 0.2	1.9	1.9	< 0.05	0.138	0.0223	9.6	< 10	< 15	15.7	1.6	219	2.038	142	130	7
8/24/2016	6	< 0.2	1.98	1.98	< 0.05	0.245	< 0.05	< 4	< 10	< 15	22.2	< 5	98.4	2.225	127	107	3
9/27/2016	6	< 0.2	2.07	2.51	< 0.05	0.599	0.037	4.4	< 10	< 15	10.1	1.7	> 2420	3.109	110	9.1	6
10/31/2016	8	< 0.2	1.5	1.5	< 0.05	0.329	< 0.05	14.5	< 10	< 15	13.8	< 5	248	1.829	121	109	7
11/17/2016	8	< 0.2	2.51	2.51	< 0.05	< 0.2	< 0.05	9.6	< 10	< 15	11.9	2.9	55.6	2.51	154	139	5
12/20/2016	< 2	< 0.2	1.63	1.63	< 0.05	0.458	< 0.05	< 4	< 10	< 1	20.3	< 5	88.4	2.088	151	325	4
1/30/2017	< 3	< 0.2	1.83	1.83	< 0.05	0.222	< 0.05	< 5	< 10	< 1	17.7	< 5	20.6	2.052	151	188	2
2/23/2017	< 2	< 0.2	1.71	1.71	< 0.05	< 0.2	< 0.05	< 5	< 10	< 1	25	< 5	21.6	1.71	163	174	2
3/23/2017	< 2	< 0.2	1.59	1.59	< 0.05	0.192	< 0.05	< 4	< 10	< 1	29.1	< 5	55.6	1.782	144	262	2
4/20/2017	3	< 0.2	1.26	1.26	< 0.05	0.111	< 0.05	< 4	< 10	< 1	17.2	< 5	126	1.371	163	150	3
5/16/2017	3.22	< 0.2	3.23	3.23	< 0.05	< 0.2	< 0.05	< 4	< 10	< 1	21.3	< 5	411	3.23	241	273	0
6/27/2017	3.34	< 0.2	1.15	1.15	< 0.05	0.118	< 0.05	< 4	< 10	0.13	10.5	< 5	248	1.268	140	105	2
Station WC003																	
7/12/2016	< 2	< 0.2	1.55	1.55	< 0.05	0.319	0.0528	124	< 10	< 15	15.5	2.1	488	1.869	160	177	20
8/24/2016	< 2	< 0.2	1.3	1.3	< 0.05	0.228	< 0.05	< 4	< 10	< 15	22	< 5	210	1.528	132	119	3
9/27/2016	4	< 0.2	1.27	1.27	< 0.05	0.446	0.0287	4	< 10	< 15	9.3	2.2	1300	1.716	105	8.9	5
10/31/2016	7	< 0.2	0.766	0.766	< 0.05	0.271	< 0.05	< 5	< 10	< 15	10.7	< 5	52.8	1.037	126	106	3
11/17/2016	< 2	< 0.2	1.55	1.55	< 0.05	< 0.2	< 0.05	< 4	< 10	< 15	18	2.4	2	1.55	191	203	6
12/20/2016	< 2	< 0.2	1.34	1.34	< 0.05	0.112	< 0.05	< 4	< 10	< 1	24.1	< 5	36.8	1.452	155	255	3
1/30/2017	< 3	< 0.2	1.7	1.7	< 0.05	0.23	< 0.05	< 5	< 10	< 1	25.8	1.6	5.1	1.93	187	266	3
2/23/2017	< 2	< 0.2	1.58	1.58	< 0.05	0.305	< 0.05	8	< 10	0.11	69.6	< 5	30.5	1.885	212	225	8
3/23/2017	< 2	< 0.2	1.29	1.29	< 0.05	0.14	< 0.05	< 4	< 10	< 1	52.2	< 5	71.7	1.43	169	387	2
4/20/2017	< 2	< 0.2	1.04	1.04	< 0.05	0.237	< 0.05	< 4	< 10	< 1	65	< 5	81.3	1.277	201	223	3
5/16/2017	2.4	0.139	0.962	0.962	< 0.05	< 0.2	< 0.05	< 4	< 10	< 1	46.5	< 5	249	0.962	159	162	2
6/27/2017	< 2	< 0.2	0.726	0.726	< 0.05	0.313	< 0.05	< 4	< 10	0.14	44.5	< 5	155	1.039	153	147	2

Table 4-3. (Continued)

Baseflow Date	5-Day BOD	Ammo nia	Nitrate	Nitrate + Nitrite	Ortho-phos-phate	TKN	Total P	TSS	Cop-per (µg/l)	Lead (µg/l)	Zinc (µg/l)	TPH	E. coli (MPN/ 100 ml)	Total Nitro-gen	Hard ness	Chlor-ide	Tur-bidity
Station WC004																	
7/12/2016	< 2	< 0.2	5.36	5.36	< 0.05	< 0.2	< 0.05	< 4	< 10	< 15	17.7	< 5	488	5.36	271	385	2
8/24/2016	< 2	< 0.2	4.7	4.7	< 0.05	< 0.2	< 0.05	< 4	< 10	< 15	28.9	< 5	126	4.7	263	327	1
9/27/2016	< 3	< 0.2	1.12	1.12	< 0.05	0.561	0.0401	6	< 10	< 15	13.5	1.5	548	1.681	69	5.2	4
10/31/2016	< 3	< 0.2	2.04	2.04	< 0.05	0.23	< 0.05	< 5	< 10	< 15	13.5	< 5	1990	2.27	128	120	1
11/17/2016	< 2	< 0.2	6.11	6.11	< 0.05	< 0.2	< 0.05	< 4	< 10	< 15	23.9	< 5	153	6.11	332	344	0
12/20/2016	< 2	< 0.2	4.34	4.34	< 0.05	0.124	< 0.05	< 4	< 10	< 1	30.4	< 5	12.1	4.464	242	369	2
1/30/2017	< 3	< 0.2	4.38	4.38	< 0.05	< 0.2	< 0.05	5	< 10	< 1	28.7	< 5	10.9	4.38	278	391	1
2/23/2017	< 2	< 0.2	4.57	4.57	< 0.05	< 0.2	< 0.05	< 5	< 10	< 1	27.7	< 5	87.8	4.57	311	416	0
3/23/2017	< 2	< 0.2	2.79	2.79	< 0.05	< 0.2	< 0.05	< 4	< 10	< 1	26.5	< 5	28.8	2.79	201	514	1
4/20/2017	< 2	< 0.2	3.39	3.39	< 0.05	< 0.2	< 0.05	< 4	< 10	< 1	22.1	< 5	488	3.39	271	328	1
5/16/2017	2.4	< 0.2	1.24	1.24	< 0.05	0.115	< 0.05	< 4	< 10	< 1	20.3	2.3	58.3	1.355	139	119	2
6/27/2017	< 2	< 0.2	2.54	2.54	< 0.05	0.426	< 0.05	< 4	< 10	< 1	17.9	< 5	326	2.966	201	238	0

between the minimum detection limit and reporting limit, and flagged by the laboratory for accuracy concerns.

4.3 BASEFLOW MEAN AND STORM EVENT MEAN CONCENTRATION DATA

EMC values for each parameter were calculated at each station and for each storm event (Table 4-4). Average annual baseflow concentration and storm event mean concentration values were calculated for each pollutant at each station (Table 4-5). Average concentration data computed for storm and baseflows over the course of a year were used to characterize pollutant concentrations during the average baseflow conditions or an average stormflow event. Total annual and seasonal baseflow mean concentration, storm EMC, and load are presented in Appendix D and Appendix E, respectively.

Under baseflow conditions, average concentrations of combined nitrate plus nitrite, hardness, and *E. coli* were highest at Station WC004 compared to the other two stations downstream (Figures 4-1 through 4-7). Samples collected at Station WC003 had the highest average concentrations of total phosphorus, TPH, TSS, TKN, zinc, lead, and ammonia during baseflow conditions. Station WC002 samples had the highest average concentrations of BOD at baseflow.

Under stormflow conditions, average stormflow EMCs were highest at Station WC004 for lead and zinc only (Figures 4-1 through 4-7). The average EMC for TPH was highest at Station WC002. Average EMCs for remaining parameters, including BOD, hardness, ammonia, nitrate plus nitrite, TKN, total phosphorus, TSS, copper, and *E. coli* were highest at Station WC003. All average stormflow EMCs exceeded corresponding baseflow mean concentrations at all stations except combined nitrate plus nitrite and TPH. Note that the mean concentrations for TPH were calculated from analytical results that were flagged by the analytical laboratory and therefore may not as be as accurate as other parameters. The individual storm EMCs for chloride were highest during the snowmelt event at both stations sampled. Baseflow average annual chloride concentrations were significantly higher than the corresponding average annual storm EMCs for all stations.

Table 4-4. Storm event mean concentration results (mg/L except where indicated), July 2016 – June 2017 (non-detects set to zero).

Storm Date	Rainfall (inches)	5-Day BOD	Ammonia	Nitrate	Nitrate + Nitrite	Orthophosphate	TKN	Total P	TSS	Chloride	Copper (µg/l)	Lead (µg/l)	Zinc (µg/l)
Station WC002													
8/19/2016	0.46	5.45	0.13	0.68	0.78	0.00	0.48	0.07	13.69	29.45	1.63	0.00	11.30
9/20/2016	0.75	14.13	0.00	1.01	1.01	0.00	1.04	0.18	50.97	38.29	9.13	0.00	29.34
12/1/2016	0.96	15.55	0.00	0.81	0.81	0.00	1.14	0.14	37.46	40.76	14.26	0.00	34.67
12/7/2016	0.79	0.07	0.00	0.27	0.27	0.00	0.55	0.07	16.82	14.34	5.51	0.73	16.76
3/20/2017	Snowmelt	4.74	0.00	0.63	0.63	0.00	0.41	0.03	4.17	379.66	5.60	0.35	20.49
4/2/2017	1.49	5.59	0.01	0.40	0.40	0.00	1.05	0.17	95.38	59.07	9.83	2.03	33.97
5/7/2017	1.31	11.46	0.00	0.50	0.62	0.00	0.93	0.12	56.93	27.11	10.32	1.24	28.49
6/20/2017	0.95	17.50	0.04	0.52	0.60	0.00	1.78	0.30	119.77	29.89	14.98	4.06	64.08
Station WC003													
8/19/2016	0.46	6.49	0.00	0.61	0.61	0.00	0.57	0.08	31.96	34.53	8.91	0.00	18.78
9/20/2016	0.75	10.64	0.00	0.94	0.94	0.00	0.85	0.13	48.25	46.33	9.77	0.00	33.48
12/1/2016	0.96	10.54	0.00	1.22	1.22	0.00	1.25	0.16	61.72	60.06	13.05	1.42	52.36
12/7/2016	0.79	2.53	0.00	0.33	0.33	0.00	0.54	0.57	8.65	25.18	5.86	0.78	17.43
5/7/2017	1.31	16.57	0.14	0.35	0.48	0.00	1.04	0.13	59.81	43.41	11.60	2.09	36.99
6/20/2017	0.95	16.72	0.09	0.45	0.54	0.00	1.58	0.25	122.35	42.04	22.10	5.10	77.04
Station WC004													
8/19/2016	0.46	4.08	0.00	0.54	0.54	0.00	0.57	0.08	14.22	20.20	10.21	0.00	20.78
9/20/2016	0.75	7.39	0.00	1.42	1.42	0.00	0.74	0.09	12.72	56.39	7.01	0.00	24.28
12/1/2016	0.96	5.66	0.00	0.91	0.91	0.00	1.09	0.14	53.32	24.53	15.41	0.00	63.44
12/7/2016	0.79	0.77	0.00	0.39	0.39	0.00	0.62	0.05	26.75	10.44	7.16	1.35	32.34
3/1/2017	0.18	2.10	0.00	0.80	0.95	0.00	0.71	0.04	3.38	112.01	9.80	0.68	27.02
3/20/2017	Snowmelt	0.00	0.00	0.49	0.49	0.00	0.53	0.04	28.29	394.51	7.27	1.60	26.75
4/2/2017	1.49	3.80	0.00	0.29	0.29	0.00	0.64	0.06	35.95	129.20	9.67	1.30	39.42
5/7/2017	1.31	12.79	0.23	0.47	0.59	0.00	1.27	0.16	83.04	21.38	14.79	3.07	55.33
6/20/2017	0.95	10.73	0.07	0.34	0.41	0.00	1.51	0.25	83.94	19.76	25.31	7.23	85.95

Table 4-5. Average storm EMCs and baseflow mean concentrations, Wheel Creek Watershed, July 2016 – June 2017 (non-detects set to zero). All concentrations are in units of mg/L unless indicated.

Station	5-Day BOD	Ammonia	Nitrate	Nitrate + Nitrite	Ortho-phos-phate	TKN	Total P	TSS	Chlor-ide	Copper (µg/l)	Lead (µg/l)	Zinc (µg/l)	TPH	*E. coli* (MPN/ 100 ml)
Storm Event Mean Concentrations														
WC002	9.31	0.02	0.61	0.64	0.00	0.93	0.13	49.40	77.32	8.91	1.05	29.89	0.30	1616.00
WC003	10.58	0.04	0.65	0.69	0.00	0.97	0.22	55.46	41.92	11.88	1.57	39.35	0.00	1685.92
WC004	5.26	0.03	0.63	0.67	0.00	0.85	0.10	37.96	87.60	11.85	1.69	41.70	0.00	1175.03
MD avg[a]	14.44	N.R.	N.R.	0.85	N.R.	1.94	0.33	66.57	N.R.	17.9	12.5	143.3	N.R.	N.R.
NSQD[b]	16.94	N.R.	N.R.	1.59	N.R.	2.92	0.41	111.29	N.R.	42	41	250	2.76	N.R.
Baseflow Mean Concentrations														
WC002	3.13	0.00	1.86	1.90	0.00	0.20	0.00	3.18	164.26	0.00	0.01	17.90	0.52	334.35
WC003	1.12	0.01	1.26	1.26	0.00	0.22	0.01	11.33	189.91	0.00	0.02	33.60	0.69	223.52
WC004	0.20	0.00	3.55	3.55	0.00	0.12	0.00	0.92	296.35	0.00	0.00	22.59	0.32	359.74

N.R. = Reference data not available.
[a] = Maryland State average values from Bahr 1997.
[b] = National Stormwater Quality Database values for Maryland from Pitt 2008.

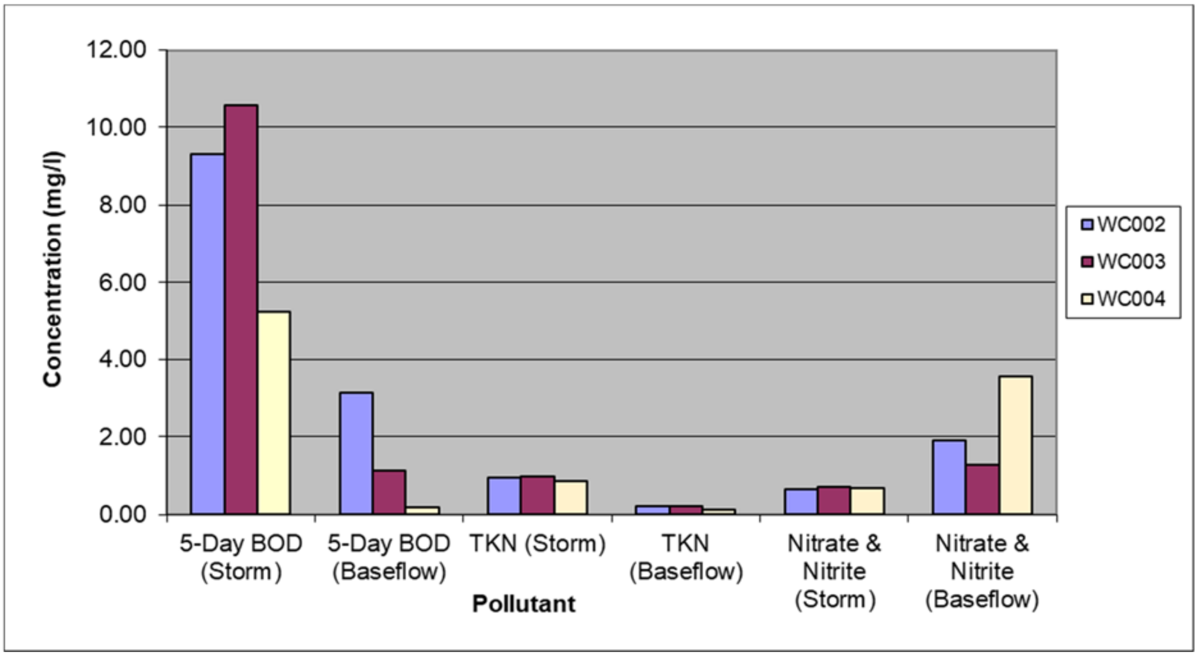

Figure 4-1. Nitrogen and 5-day BOD average storm event mean and baseflow mean concentrations in Wheel Creek, July 2016 – June 2017

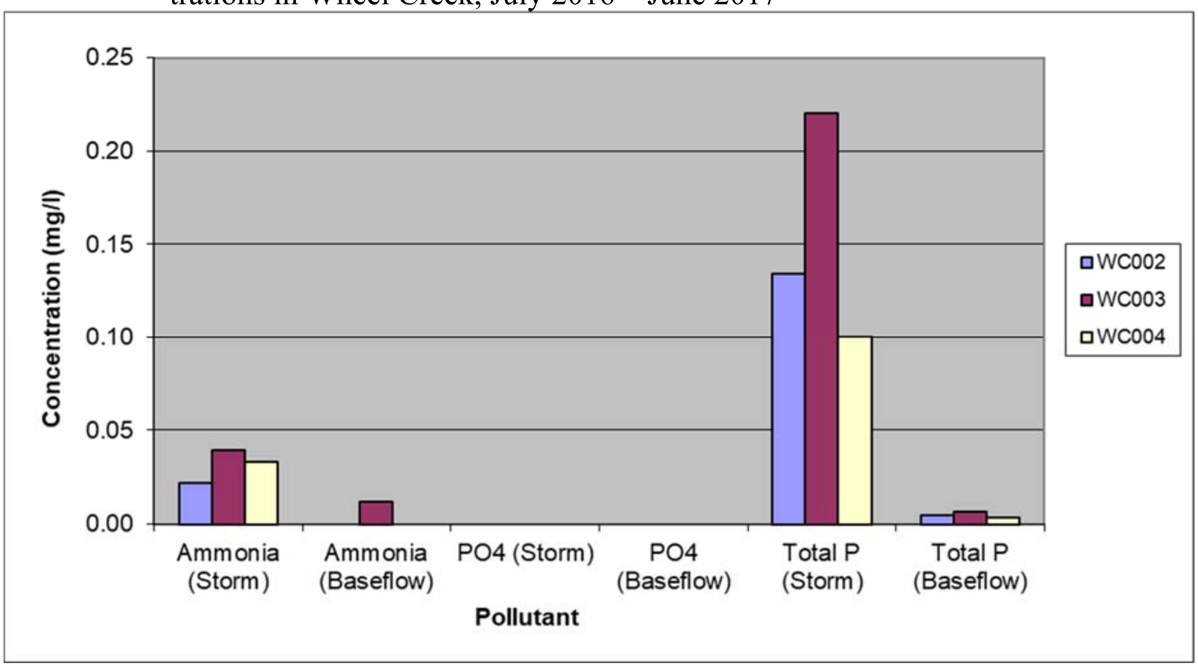

Figure 4-2. Ammonia and phosphorus average storm event mean and baseflow mean concentrations in Wheel Creek, July 2016 – June 2017

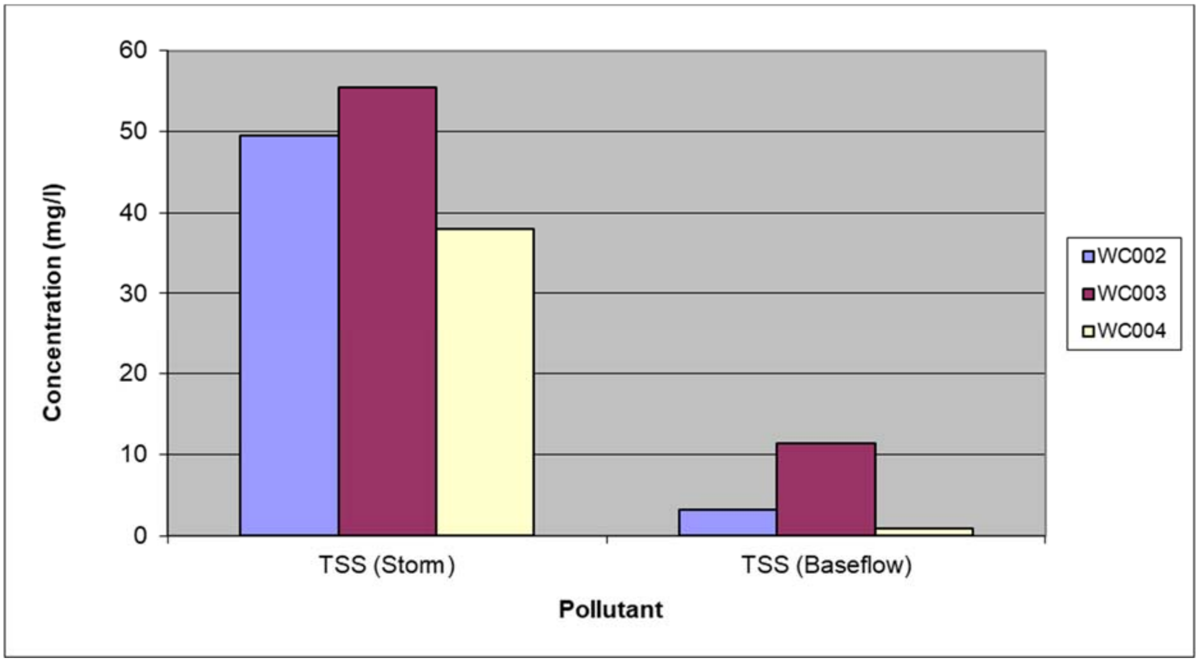

Figure 4-3. TSS average storm event and baseflow mean concentrations in Wheel Creek, July 2016 – June 2017

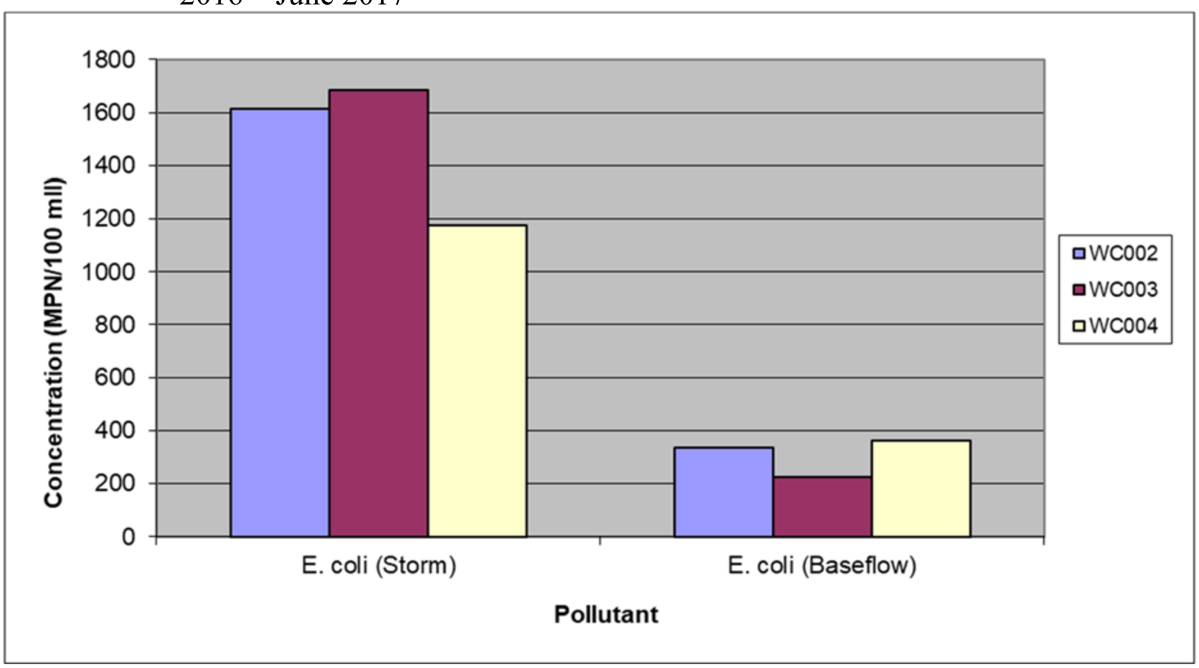

Figure 4-4. *E. coli* average storm and baseflow mean concentrations in Wheel Creek, July 2016 – June 2017

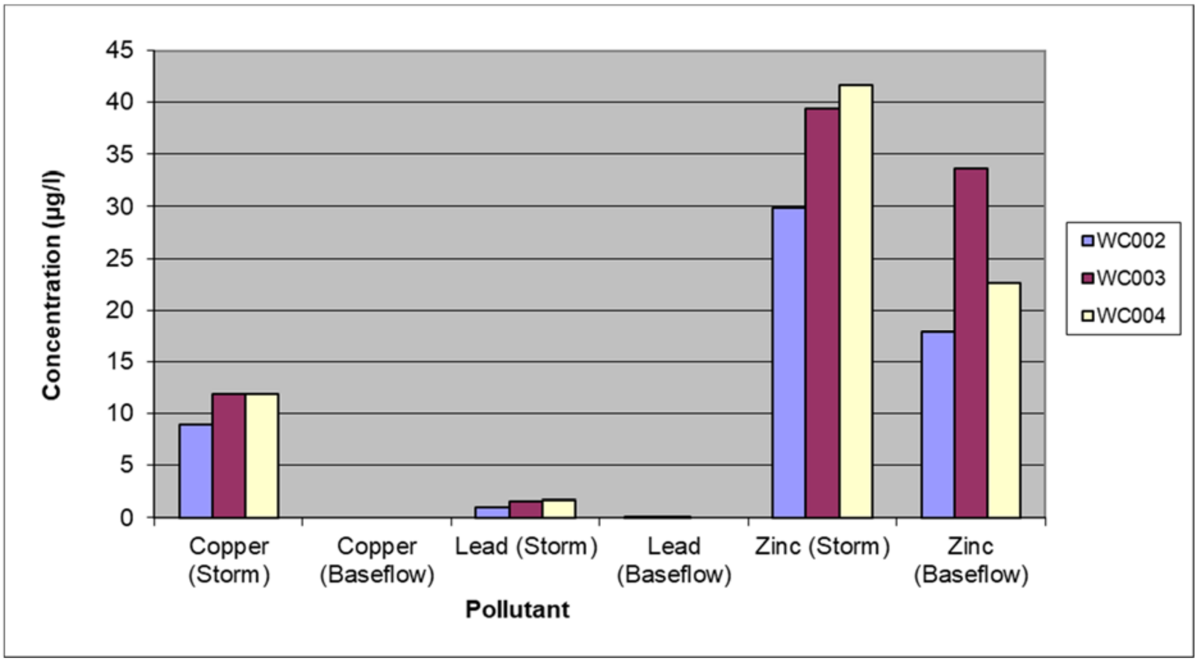

Figure 4-5. Metal average storm event mean and baseflow mean concentrations in Wheel Creek, July 2016 – June 2017

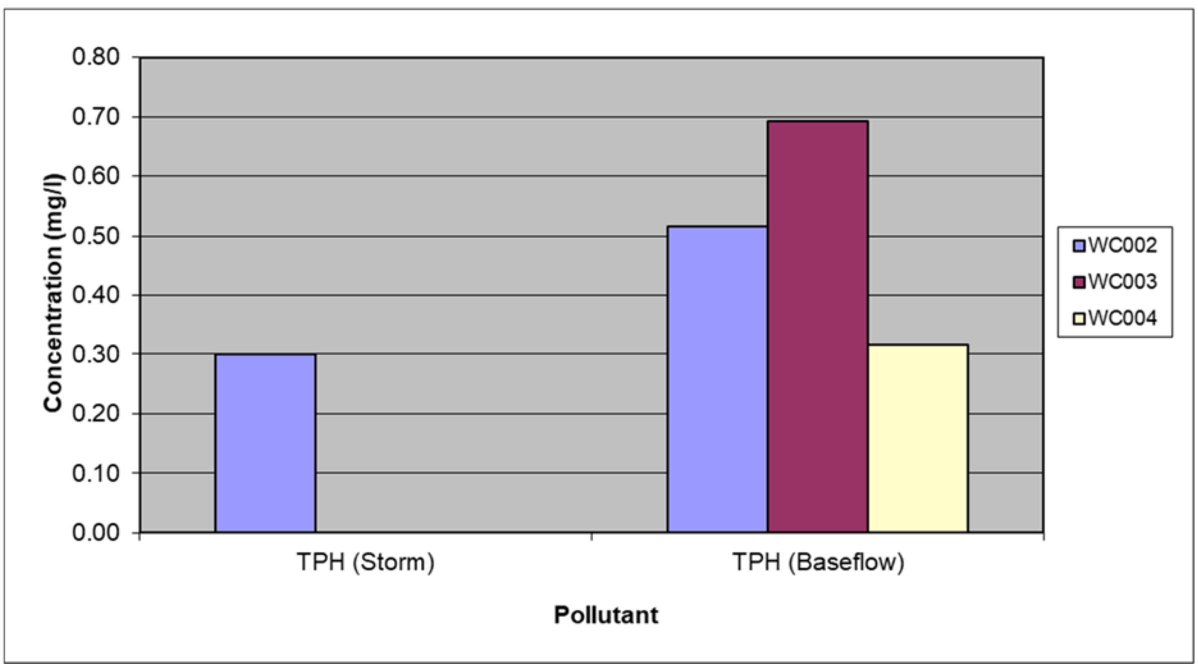

Figure 4-6. TPH storm event mean and baseflow mean concentrations in Wheel Creek, July 2016 – June 2017

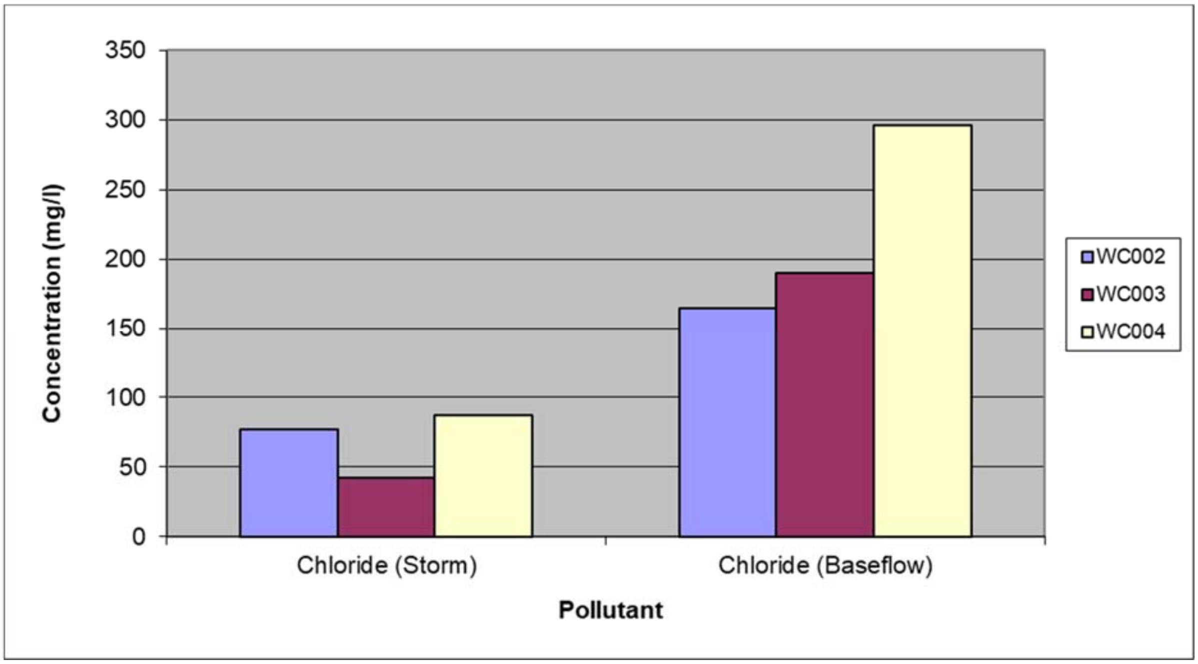

Figure 4-7. Chloride storm event mean and baseflow mean concentrations in Wheel Creek, July 2016 – June 2017

4.4 STORMFLOW POLLUTANT LOADING DATA

Pollutant loads for individual storms at each station were calculated from individual stormflow event mean concentration data (Table 4-6). Pollutant load represents the quantity of pollutant, in pounds, that was transported in the stream during the event. For discussion purposes, an average load was determined for each pollutant at each station for storms monitored from July 2016 through June 2017. Annual load estimations for WC003 are slightly underestimated due to a period of missing flow data in Winter 2017. The winter seasonal load estimates for WC003 are similarly left blank in Appendix E.

When comparing stations, average storm loads were highest at Station WC002 for all parameters except ammonia (Table 4-7). The highest average load for ammonia was calculated at Station WC003. Average loads were lowest at Station WC004 for all parameters. Since discharge volume for a given storm increases with distance downstream, maximum load results at Station WC002 are not unexpected. The cause of the comparatively high, average ammonia load at WC003 is unknown; during the prior monitoring period, the average load for ammonia at this station was anomalously low.

Average storm loads were also highest at Station WC002 for filtered nitrate plus nitrite, filtered TKN, and filtered total phosphorus (Table 4-8). Station WC004 results showed the lowest average filtered storm loads for TKN and combined nitrate plus nitrite. The average filtered nitrate plus nitrite load was higher than the corresponding unfiltered load at all stations due to unknown reasons, possibly variability in concentration data magnified by discharge volume per event. Average filtered total phosphorous loads at the three stations were between 0.8% and 4.1% of the corresponding whole sample, confirming that total phosphorus is predominantly carried by particulate matter.

Table 4-6. Storm event pollutant loadings (lbs per event), July 2016 – June 2017 (non-detects set to zero).

Storm Date	Discharge (cf)	5-Day BOD	Ammonia	Nitrate	Nitrate + Nitrite	Ortho-phos-phate	TKN	Total P	TSS	Chloride	Copper	Lead	Zinc
Station WC002													
8/19/2016	80,401	27.38	0.63	3.43	3.93	0.00	2.43	0.35	68.69	147.80	0.01	0.00	0.06
9/20/2016	137,914	121.67	0.00	8.74	8.74	0.00	8.98	1.56	438.82	329.68	0.08	0.00	0.25
12/1/2016	211,847	205.66	0.00	10.77	10.77	0.00	15.13	1.89	495.40	539.07	0.19	0.00	0.46
12/7/2016	231,320	1.00	0.00	3.97	3.97	0.00	7.93	1.00	242.86	207.02	0.08	0.01	0.24
3/20/2017	56,189	16.62	0.00	2.22	2.22	0.00	1.46	0.10	14.62	1331.78	0.02	0.00	0.07
4/2/2017	706,345	246.64	0.46	17.79	17.79	0.00	46.49	7.46	4205.78	2604.62	0.43	0.09	1.50
5/7/2017	461,504	330.16	0.00	14.27	17.78	0.00	26.83	3.33	1640.08	780.93	0.30	0.04	0.82
6/20/2017	286,995	313.50	0.70	9.33	10.81	0.00	31.92	5.31	2145.81	535.45	0.27	0.07	1.15
Station WC003													
8/19/2016	43,812	17.76	0.00	1.67	1.67	0.00	1.56	0.21	87.42	94.43	0.02	0.00	0.05
9/20/2016	71,327	47.39	0.00	4.17	4.17	0.00	3.78	0.58	214.83	206.29	0.04	0.00	0.15
12/1/2016	111,430	73.31	0.00	8.46	8.46	0.00	8.68	1.10	429.38	417.79	0.09	0.01	0.36
12/7/2016	132,452	20.92	0.00	2.74	2.74	0.00	4.49	4.75	71.50	208.19	0.05	0.01	0.14
5/7/2017	191,706	198.26	1.72	4.17	5.79	0.00	12.44	1.59	715.77	519.48	0.14	0.03	0.44
6/20/2017	113,346	118.30	0.65	3.18	3.80	0.00	11.19	1.73	865.73	297.47	0.16	0.04	0.55
Station WC004													
8/19/2016	29,105	7.41	0.00	0.98	0.98	0.00	1.04	0.14	25.83	36.71	0.02	0.00	0.04
9/20/2016	57,724	26.61	0.00	5.11	5.11	0.00	2.66	0.32	45.84	203.21	0.03	0.00	0.09
12/1/2016	122,255	43.17	0.00	6.97	6.97	0.00	8.36	1.04	406.92	187.18	0.12	0.00	0.48
12/7/2016	86,558	4.15	0.00	2.09	2.09	0.00	3.34	0.29	144.57	56.39	0.04	0.01	0.17
3/1/2017	12,312	1.61	0.00	0.61	0.73	0.00	0.54	0.03	2.60	86.09	0.01	0.00	0.02
3/20/2017	9,178	0.00	0.00	0.28	0.28	0.00	0.31	0.02	16.21	226.04	0.00	0.00	0.02
4/2/2017	118,104	27.99	0.00	2.17	2.17	0.00	4.70	0.44	265.06	952.57	0.07	0.01	0.29
5/7/2017	107,214	85.61	1.54	3.17	3.96	0.00	8.51	1.07	555.79	143.11	0.10	0.02	0.37
6/20/2017	58,061	38.89	0.25	1.24	1.48	0.00	5.48	0.90	304.26	71.63	0.09	0.03	0.31

Table 4-7. Average storm pollutant loads (lbs/event), Wheel Creek monitoring, July 2016 – June 2017 (non-detects set to zero)

Station	5-Day BOD	Ammonia	Nitrate	Nitrate + Nitrite	Ortho-phosphate	TKN	Total P	TSS	Chloride	Copper	Lead	Zinc
WC002	157.83	0.22	8.82	9.50	0.00	17.65	2.62	1156.51	809.54	0.17	0.03	0.57
WC003	79.32	0.40	4.06	4.44	0.00	7.02	1.66	397.44	290.61	0.08	0.01	0.28
WC004	26.16	0.20	2.51	2.64	0.00	3.88	0.47	196.34	218.10	0.05	0.01	0.20

Table 4-8. Average filtered storm pollutant loads (lbs/event), Wheel Creek monitoring, July 2016 – June 2017 (non-detects set to zero)

Station	Nitrate + Nitrite	TKN	Total P
WC002	10.73	10.29	0.09
WC003	4.91	3.74	0.01
WC004	2.68	2.04	0.02

4.5 NUTRIENT SYNOPTIC SAMPLING RESULTS

In 2017, five of the eight sampled stations in the Wheel Creek watershed were found to have moderate amounts of nitrate plus nitrite concentrations (Table 4-9, Figure 4-8). The remaining three stations sampled, W2, W5, and W7, fell in the baseline category. Station W8 had the highest nitrate plus nitrite concentration in 2017, as was also the case in 2015 and 2016. The concentration, however, changed from the high to moderate category. The highest nitrate plus nitrite yields were found at Stations W5 and W6 (Figure 4-10). Both stations were located on the same tributary and the concentrations fell into the moderate category. All other stations sampled were in the baseline category for nitrate plus nitrite yield. All but one of the stations sampled, W5, were below the reporting limit for orthophosphate (Figure 4-12). Station W5 was in the excessive category for orthophosphate; however, it is important to note that the reporting limit was 0.05 mg/L and any result above this concentration will fall into the excessive category. All orthophosphate yields were found to be in the baseline category at every station except Station W5, where a high yield was evident (Figure 4-14), probably because of the excessive concentration.

In contrast to the Wheel Creek Watershed, the reference watershed's nitrate plus nitrite concentrations and yields were in the baseline category for all stations sampled (Table 4-9, Figures 4-9 and 4-11). The orthophosphate results were similar to what was found in the Wheel Creek watershed (Figures 4-13 and 4-15). Orthophosphate concentrations at all reference stations were below the reporting limit. Yields for all but one reference station, R5, were in the baseline category. The yield category for Station R5 could not be precisely determined because the yield was calculated from a below-detection limit result, but fell in the range between baseline and high.

Table 4-9. Nutrient synoptic sampling results, April 2017

Watershed	Station	Catchment Size (ha)	Nitrate + Nitrite Concentration (mg/L)	Orthophosphate Concentration (mg/L)	Discharge (CF/day)	Nitrate + Nitrite Yield (kg/ha/day)	Orthophosphate Yield (kg/ha/day)
Wheel Creek	W1	176	1.14	< 0.05	29,376	0.0054	< 0.00024
	W2	16	0.517	< 0.05	237	0.0002	< 0.00002
	W3	41	1.14	< 0.05	9,231	0.0073	< 0.00032
	W4	28	1.07	< 0.05	1,370	0.0015	< 0.00007
	W5	46	0.637	0.06	34,996	0.0137	0.00129
	W6	10	1.31	< 0.05	3,713	0.0138	< 0.00053
	W7	15	0.243	< 0.05	1,788	0.0008	< 0.00017
	W8	17	2.06	< 0.05	596	0.0020	< 0.00005
Reference	R1	209	0.517	< 0.05	64,035	0.0045	< 0.00043
	R2	9	0.497	< 0.05	534	0.0008	< 0.00008
	R3	16	0.825	< 0.05	4,736	0.0069	< 0.00042
	R4	14	0.4	< 0.05	4,022	0.0033	< 0.00041
	R5	127	0.398	< 0.05	110,673	0.0098	< 0.00123
	R6	109	0.793	< 0.05	31,754	0.0065	< 0.00041
	R7	27	0.61	< 0.05	3,084	0.0020	< 0.00016
	R8	29	0.181	< 0.05	1,669	0.0003	< 0.00008
Nutrient Level Rating							
Baseline			< 1	< 0.005		< 0.01	< 0.0005
Moderate			1 to 3	0.005 to 0.01		0.01 to 0.02	0.0005 to 0.001
High			3 to 5	0.01 to 0.015		0.02 to 0.03	0.001 to 0.002
Excessive			> 5	> 0.015		> 0.03	> 0.002

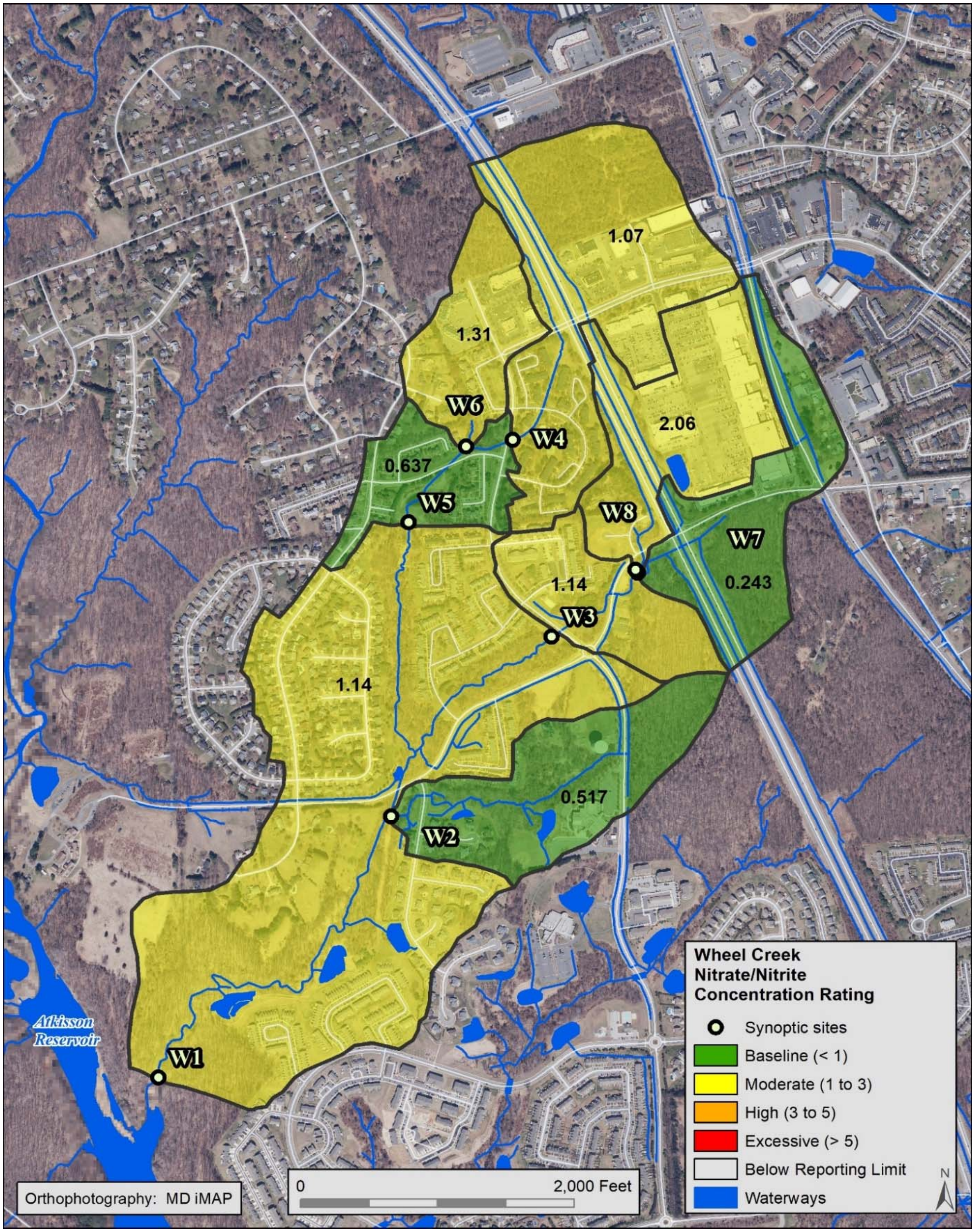

Figure 4-8. Synoptic combined nitrate plus nitrite concentrations (mg/L) and ratings, Wheel Creek, April 2017

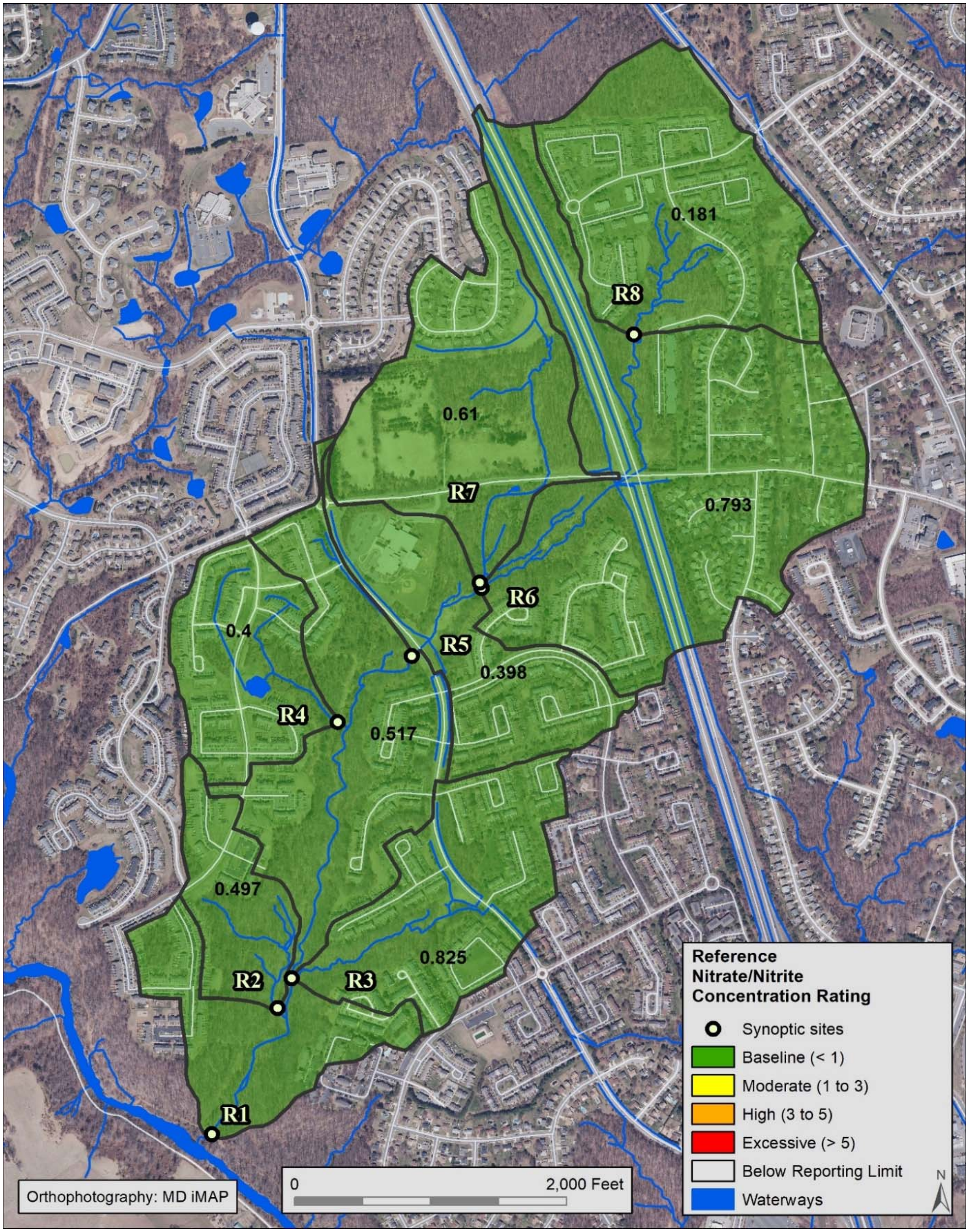

Figure 4-9. Synoptic combined nitrate plus nitrite concentrations (mg/L) and ratings, Reference watershed, April 2017

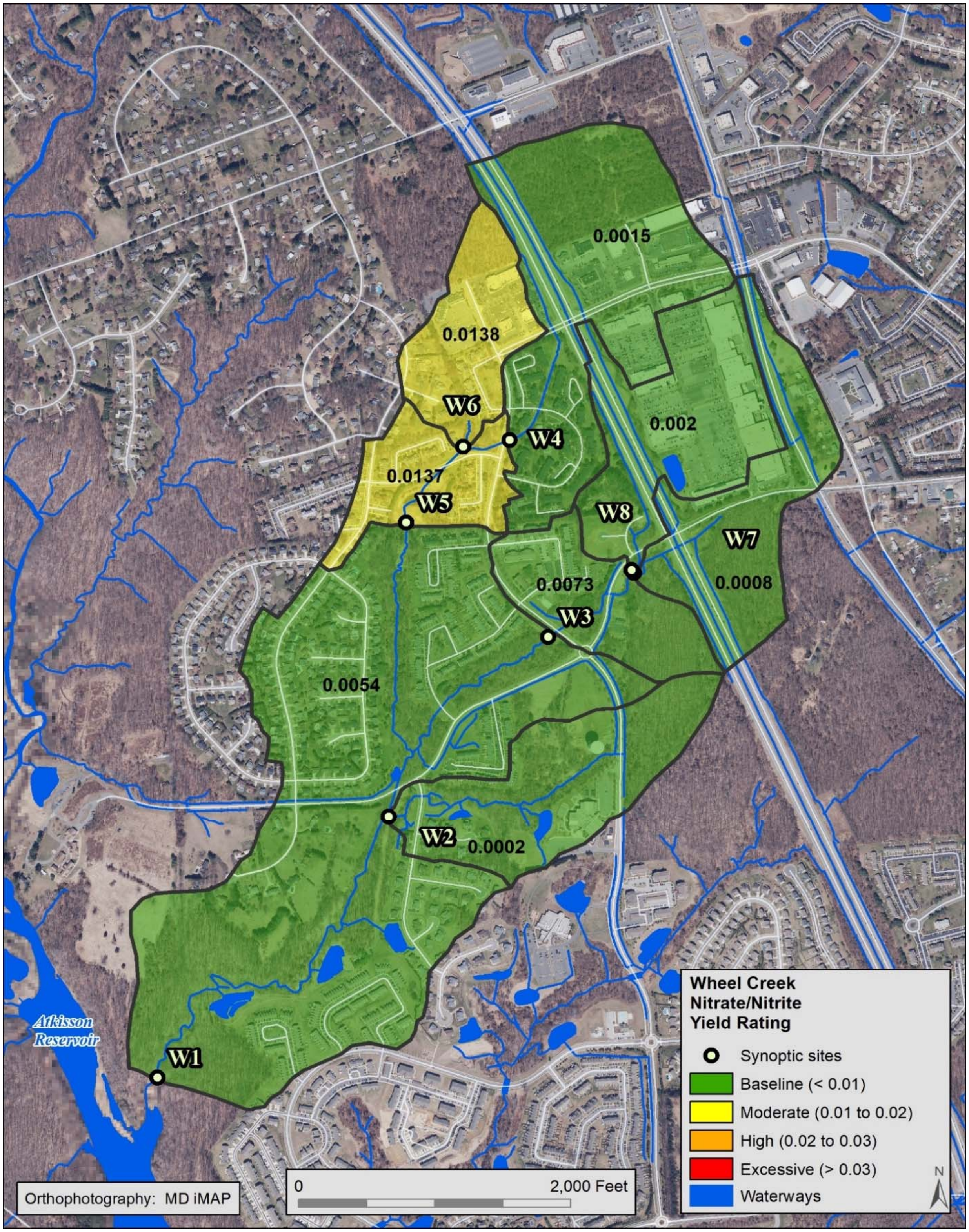

Figure 4-10. Synoptic combined nitrate plus nitrite yields (kg/ha/day) and ratings, Wheel Creek, April 2017

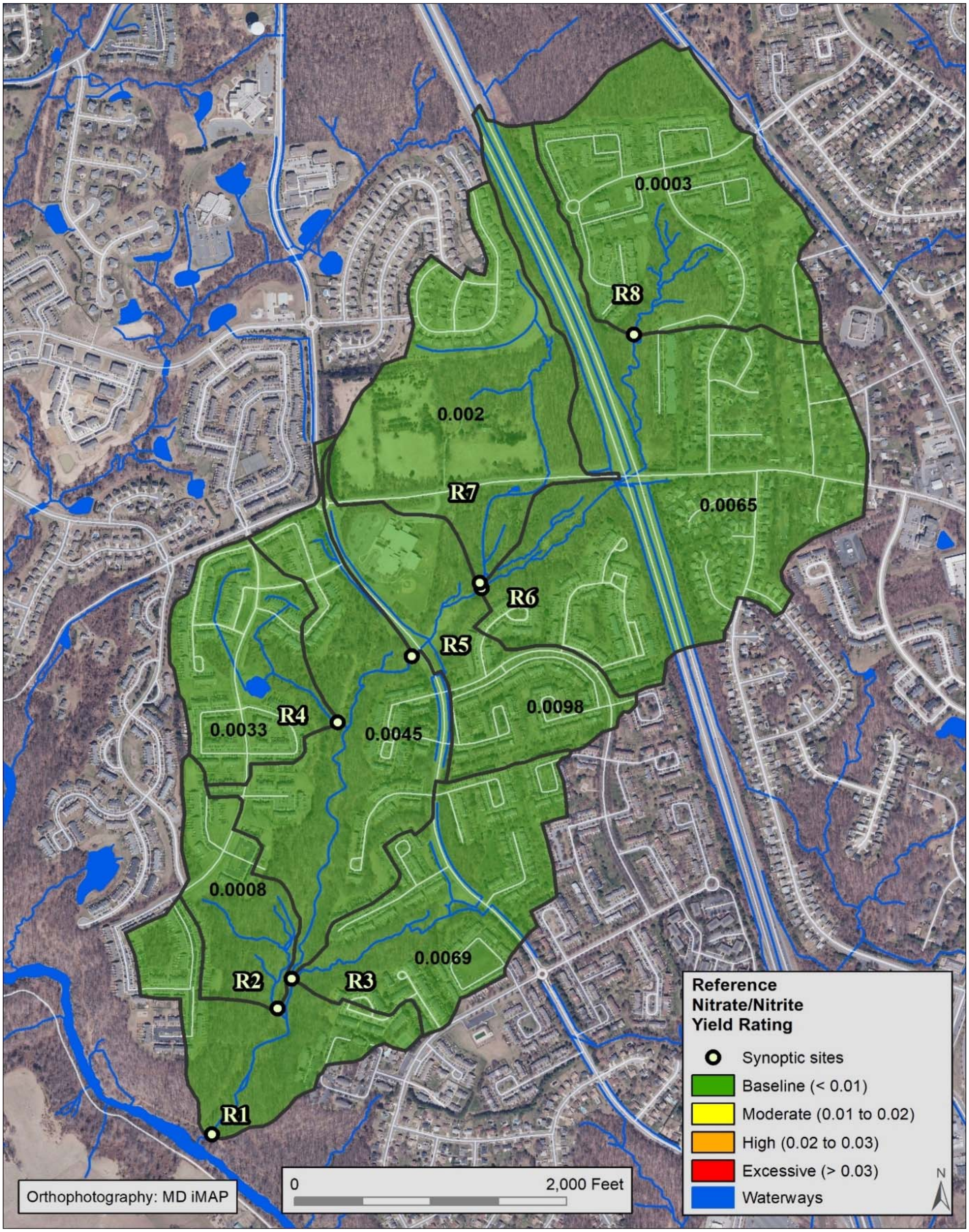

Figure 4-11. Synoptic combined nitrate plus nitrite yields (kg/ha/day) and ratings, Reference watershed, April 2017

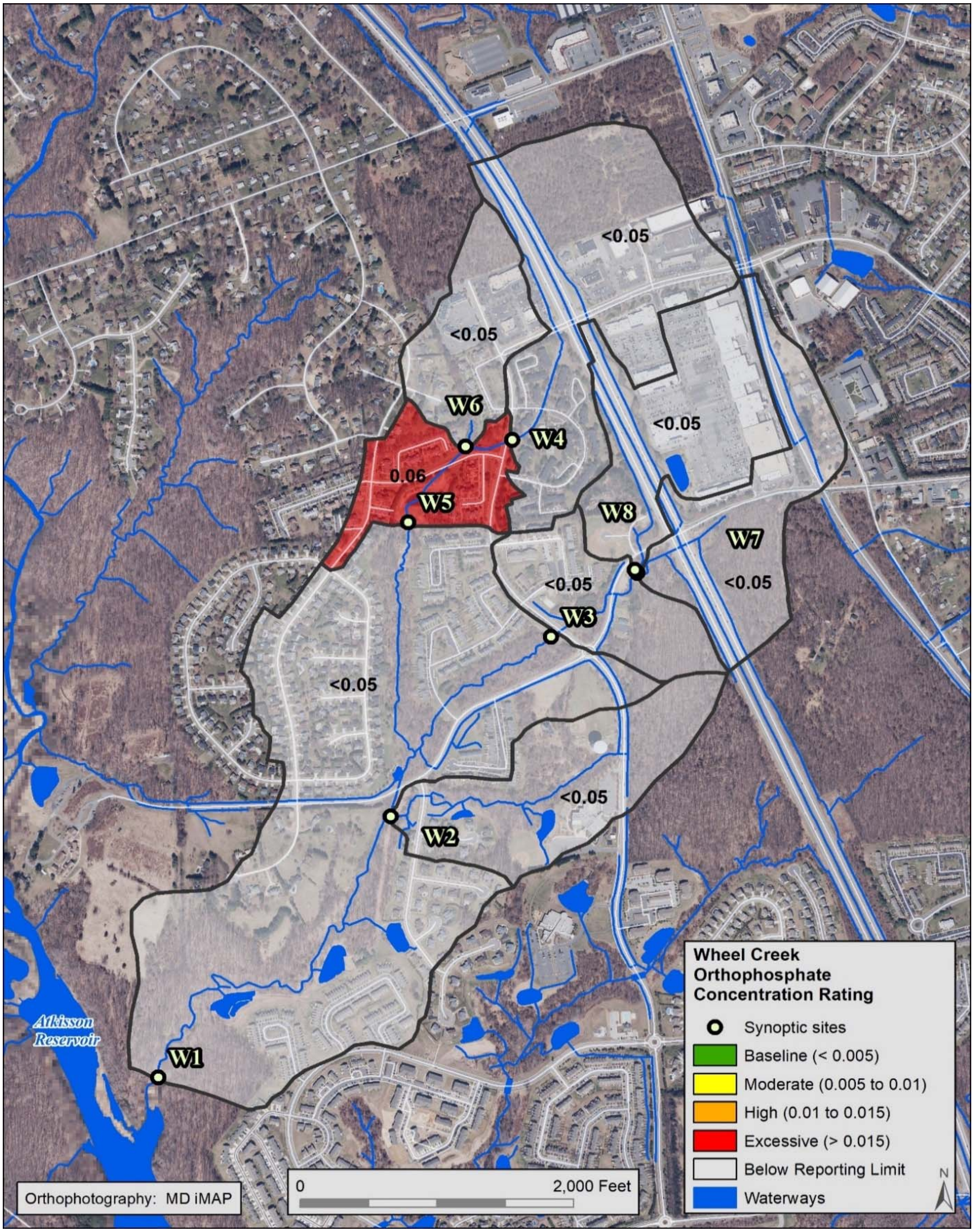

Figure 4-12. Synoptic orthophosphate concentrations (mg/L) and ratings, Wheel Creek, April 2017

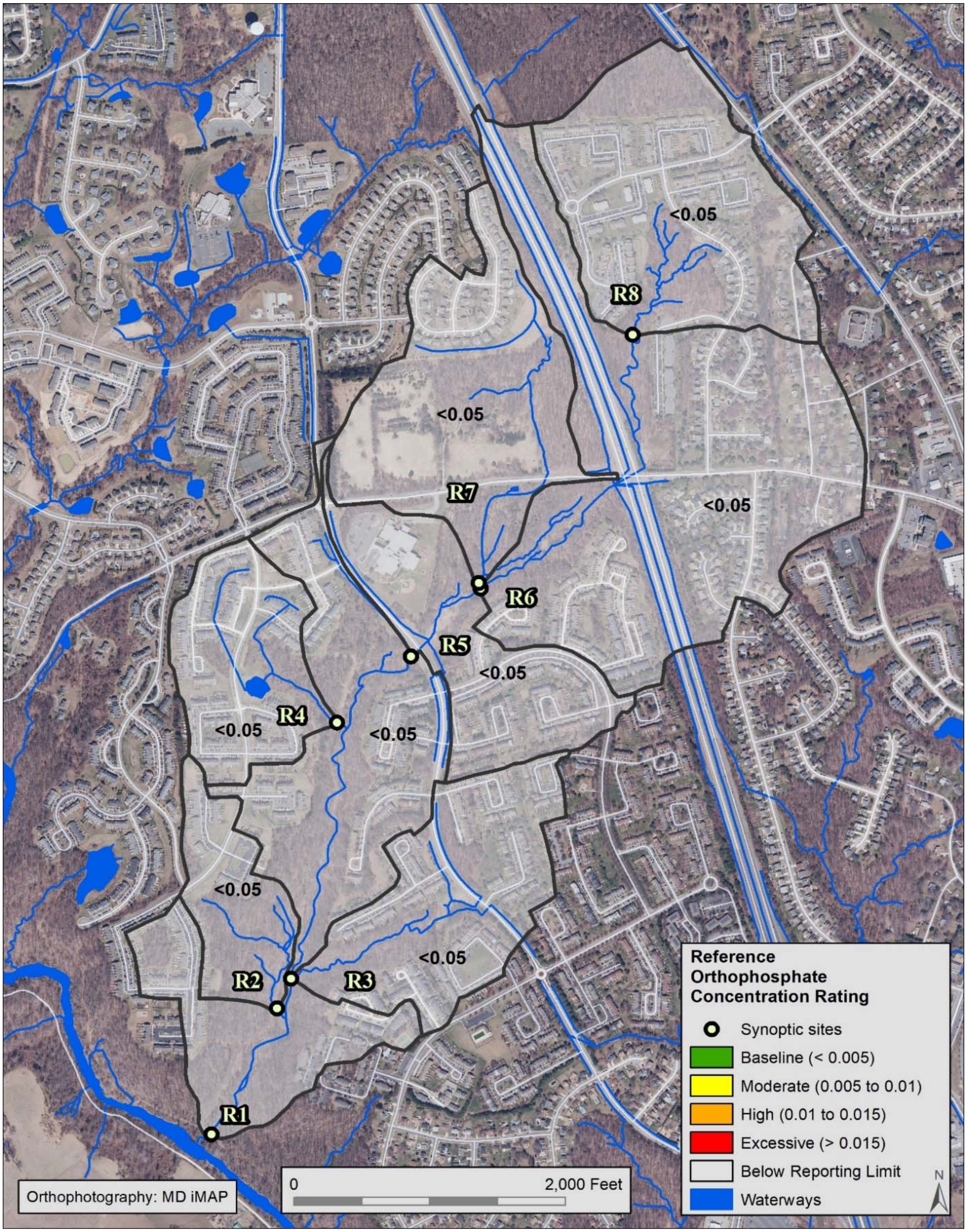

Figure 4-13. Synoptic orthophosphate concentrations (mg/L) and ratings, Reference watershed, April 2017

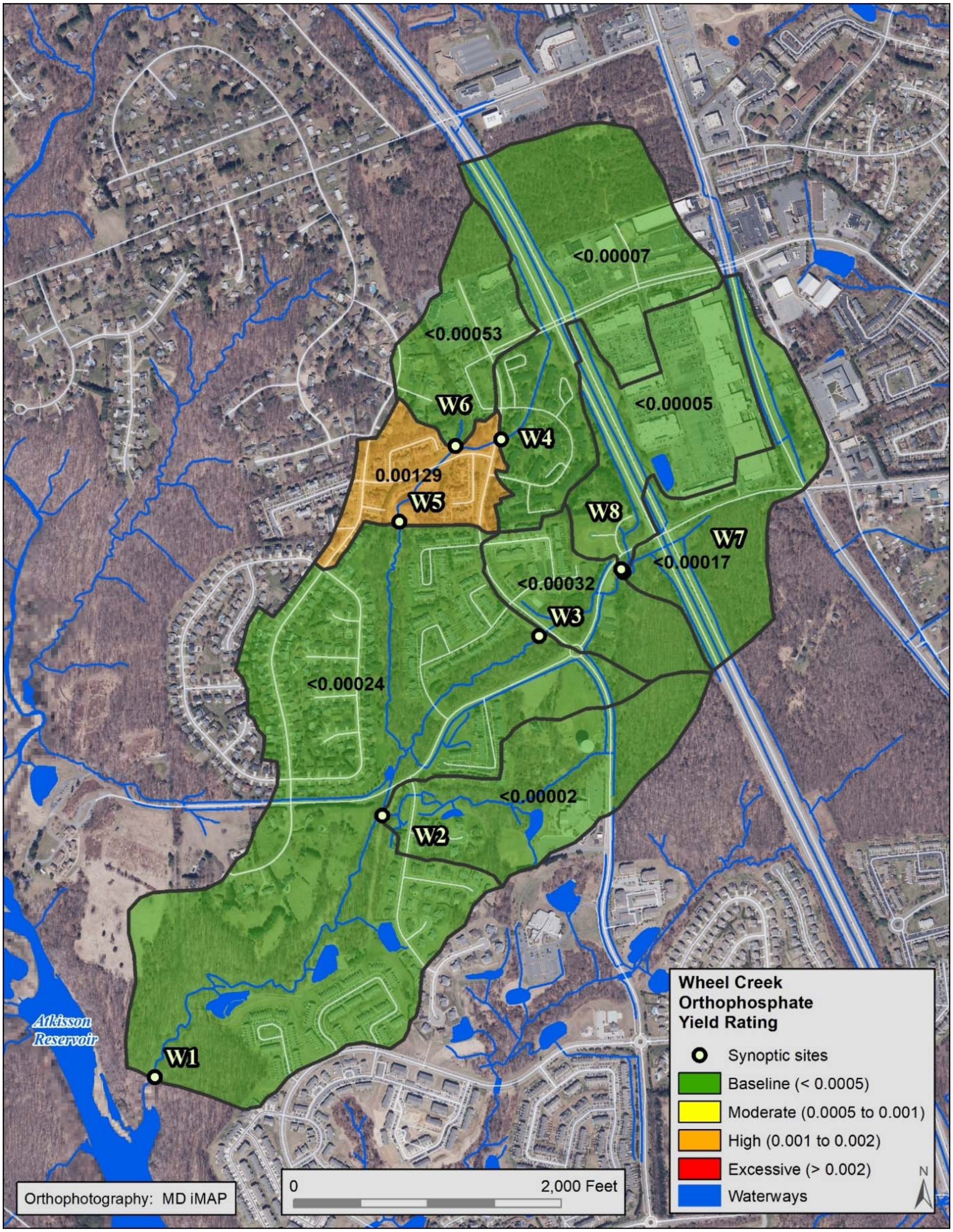

Figure 4-14. Synoptic orthophosphate yields (kg/ha/day) and ratings, Wheel Creek, April 2017

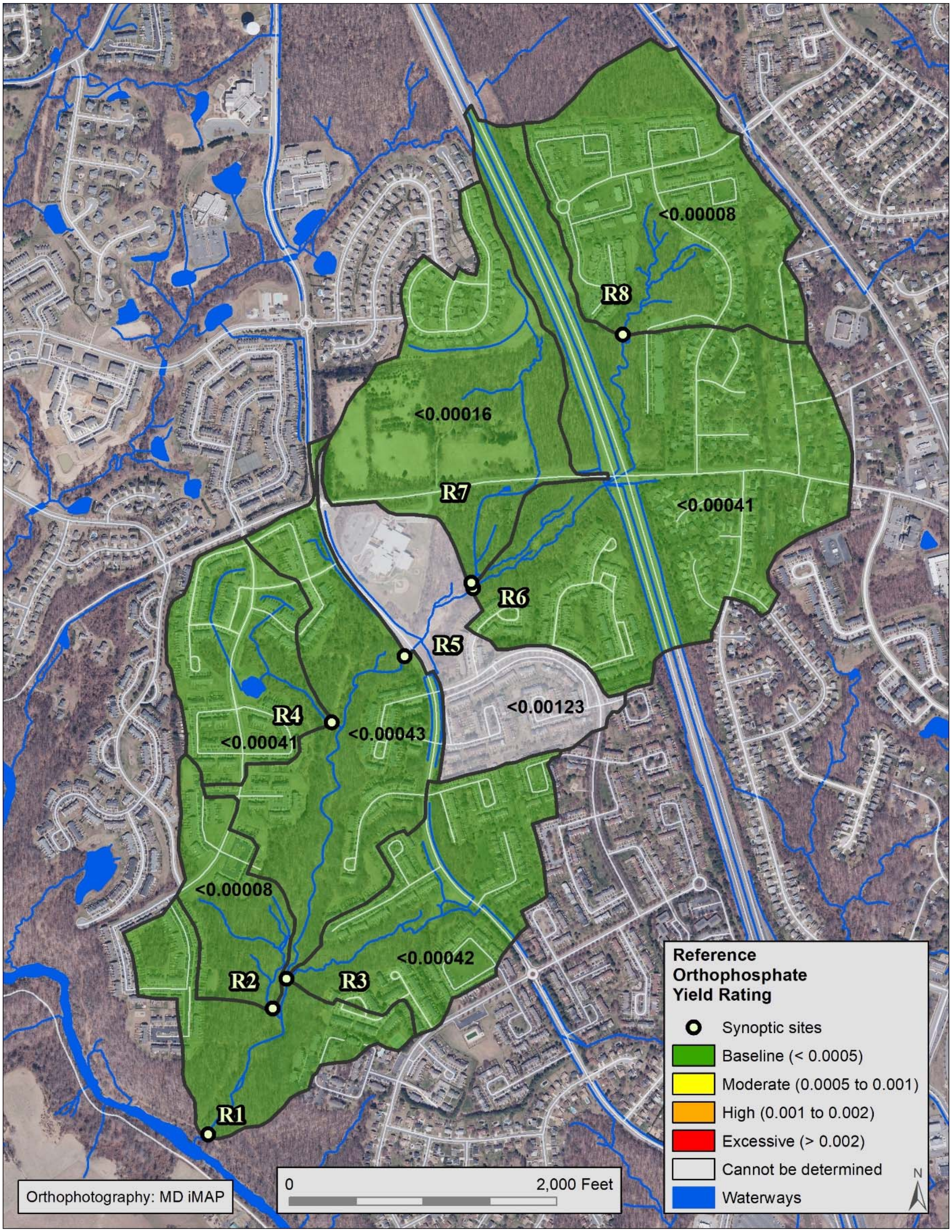

Figure 4-15. Synoptic orthophosphate yields (kg/ha/day) and ratings, Reference watershed, April 2017

4.6 SEDIMENT TRANSPORT SAMPLING RESULTS

A summary of suspended sediment transport data and suspended sediment transport curves for Stations WC002, WC003, and WC004 are presented below. The discharges associated with each sediment sample were approximated from flow rate data recorded at the time when the stage at which the samplers filled, as shown by stage loggers attached to the siphon samplers, was achieved. Samples that filled prior to storm flow were presumed to represent baseflow conditions and were not included in development of the sediment rating curves.

During nine sampling events from July 2016 to June 2017, a total of 35 samples were collected at Station WC002 (Table 4-10) and 16 samples were collected at Station WC004 (Table 4-12). For the six sampling events at Station WC003, 25 samples were collected (Table 4-11). Suspended sediment concentrations ranged from 5.4 to 545 mg/L at Station WC002, 4.2 to 639 mg/L at Station WC003, and 6.6 to 219 mg/L at Station WC004.

Sediment transport curves were created for each station using discharges that were determined at time of filling, and concentration of suspended sediment in samples. Because of anomalously high suspended sediment concentrations during the May and June storms, two separate curves are presented for Stations WC002 and WC003 that show results before and after the pond/culvert construction completion at Station WC003 in April 2017. Station WC004, located upstream of the construction activity, was unaffected, therefore only one curve is presented. The outlier suspended sediment concentrations may have been caused by the removal of sediment controls after construction, causing a large amount of fine particles to be transported in the storm flows occurring shortly after. Including the May and June 2017 sediment results at Station WC002 resulted in poor correlation between discharge and sediment concentration ($r^2 = 0.16$). After omitting the May and June sediment results, the curve showed an improved relationship between discharge and sediment concentration (Figure 4-16, $r^2 = 0.866$). The May and June sediment results at Station WC002 show a poor relationship between discharge and sediment concentration (Figure 4-17, $r^2 = 0.095$). Corresponding transport curves prepared for Station WC003 showed poor correlation between discharge and suspended sediment concentration ($r^2 = 0.11$ and $r^2 = 0.137$, respectively) during both before and after construction time periods (Figures 4-18 and 4-19). The sediment transport curve at Station WC004, consisting of samples collected throughout the period, also had a poor relationship between discharge and sediment concentration ($r^2 = 0.011$; Figure 4-20). The variability in sediment concentrations at Station WC003 and Station WC004 could be due to a limited amount of data, channel stability, or instances when siphon samplers were not effective (e.g., copper intake pipe can easily be restricted by sediment). Correlation between discharge and sediment concentration improved at Station WC002 but no significant change was noted at Stations WC003 and WC004 from last year.

The arithmetic mean of stormflow-associated suspended sediment concentrations, by station, exceeded corresponding EMCs of TSS, suggesting that TSS results underestimate the actual transport of sediment during storms.

Table 4-10. Suspended sediment results at Station WC002, July 2016 - June 2017							
Date	**Bottle Number**	**Suspended Sediment (mg/L)**	**Discharge (cfs)**	**Date**	**Bottle Number**	**Suspended Sediment (mg/L)**	**Discharge (cfs)**
18-Aug-16	1	72.6	0.2	18-Mar-17	1	5.4	0.99
18-Aug-16	2	73.7	0.2	18-Mar-17	2	5.8	0.99
18-Aug-16	3	66.4	0.36	18-Mar-17	3	11.5	0.99
18-Aug-16	4	38.9	0.48	31-Mar-17	1	17.4	0.32
19-Sep-16	1	24	0.2	31-Mar-17	2	12.2	0.32
19-Sep-16	2	129	0.21	31-Mar-17	3	44.4	0.32
19-Sep-16	3	331	0.21	31-Mar-17	4	26.2	1.15
29-Nov-16	1	73.7	0.26	31-Mar-17	5	163	5.43
29-Nov-16	2	33.3	0.26	31-Mar-17	6	249	13.98
29-Nov-16	3	55	0.26	5-May-17	1	12.6	0.27
29-Nov-16	4	48.9	0.37	5-May-17	2	55.9	0.42
7-Dec-16	1	26.1	0.18	5-May-17	3	128	0.65
7-Dec-16	2	15.1	0.18	5-May-17	4	191	3.36
7-Dec-16	3	35.9	0.18	5-May-17	5	249	6.83
7-Dec-16	4	30.3	0.5	19-Jun-17	1	371	0.3
1-Mar-17	1	11	0.37	19-Jun-17	2	487	0.39
1-Mar-17	2	9.9	0.37	19-Jun-17	3	388	0.53
				19-Jun-17	4	545	6.34

Table 4-11. Suspended sediment results at Station WC003, July 2016 - June 2017							
Date	**Bottle Number**	**Suspended Sediment (mg/L)**	**Discharge (cfs)**	**Date**	**Bottle Number**	**Suspended Sediment (mg/L)**	**Discharge (cfs)**
18-Aug-16	1	127	1.14	6-Dec-16	3	293	1.89
18-Aug-16	2	172	2.5	6-Dec-16	4	59.2	1.68
18-Aug-16	4	4.2	6.76	5-May-17	1	119	1.45
19-Sep-16	1	493	0.23	5-May-17	2	113	0.45
19-Sep-16	2	294	6.01	5-May-17	3	149	6.85
19-Sep-16	3	144	9.52	5-May-17	4	151	8.51
19-Sep-16	4	22.2	11.19	5-May-17	5	453	8.46
29-Nov-16	1	141	13.35	5-May-17	6	349	4.33
29-Nov-16	2	18.1	11.95	19-Jun-17	1	478	0.14
29-Nov-16	4	5	0.16	19-Jun-17	3	503	0.61
6-Dec-16	1	206	1.21	19-Jun-17	4	580	0.11
6-Dec-16	2	58.9	1.73	19-Jun-17	5	438	0.15
				19-Jun-17	6	639	1.21

Table 4-12. Suspended sediment results at Station WC003, July 2016 - June 2017							
Date	**Bottle Number**	**Suspended Sediment (mg/L)**	**Discharge**	**Date**	**Bottle Number**	**Suspended Sediment (mg/L)**	**Discharge**
18-Aug-16	1	146	0.04	31-Mar-17	1	22.9	2
19-Sep-16	1	12.2	0.23	31-Mar-17	2	97.7	2.13
19-Sep-16	2	22.6	0.23	31-Mar-17	4	47.5	3.39
29-Nov-16	1	31.7	0.11	5-May-17	1	57.6	1.45
29-Nov-16	2	15.3	0.59	5-May-17	2	57.9	1.65
7-Dec-16	1	20.6	0.45	5-May-17	4	31	3.32
1-Mar-17	2	8.6	0.13	19-Jun-17	1	219	0.09
19-Mar-17	3	6.6	0.63	19-Jun-17	2	83.8	1.46

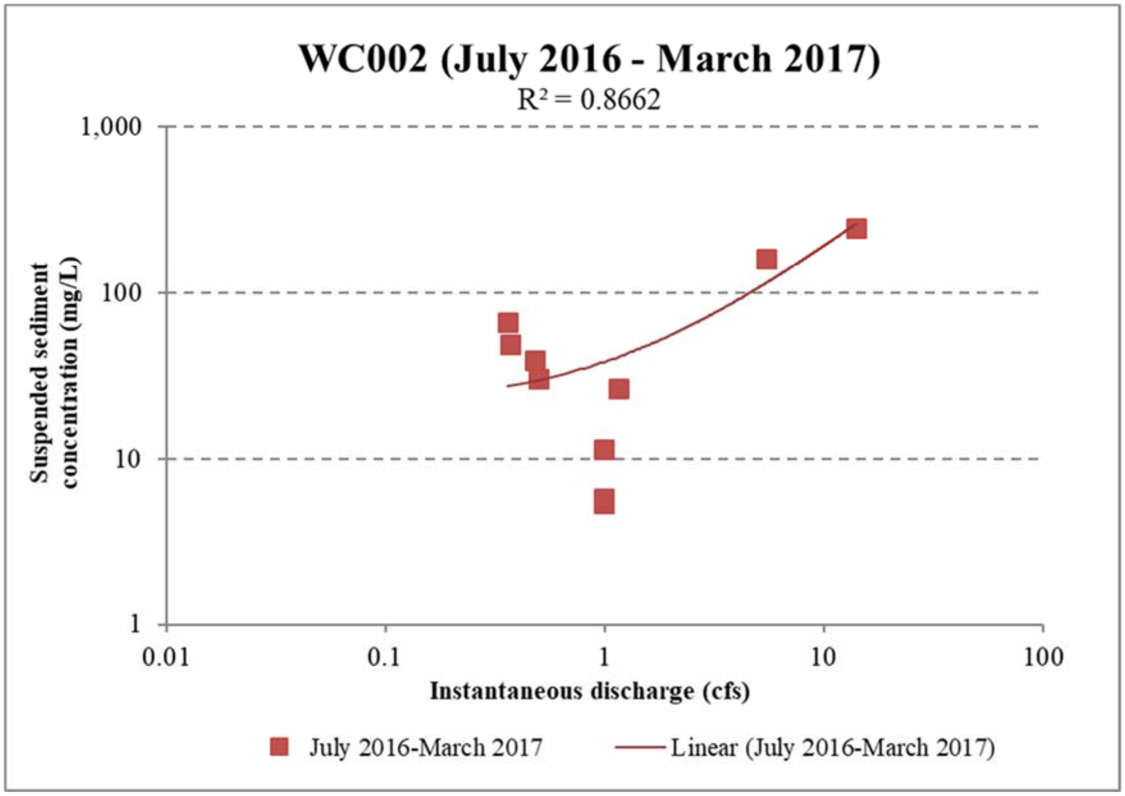

Figure 4-16. Suspended sediment curve for Wheel Creek Station 002 (July 2016-March 2017)

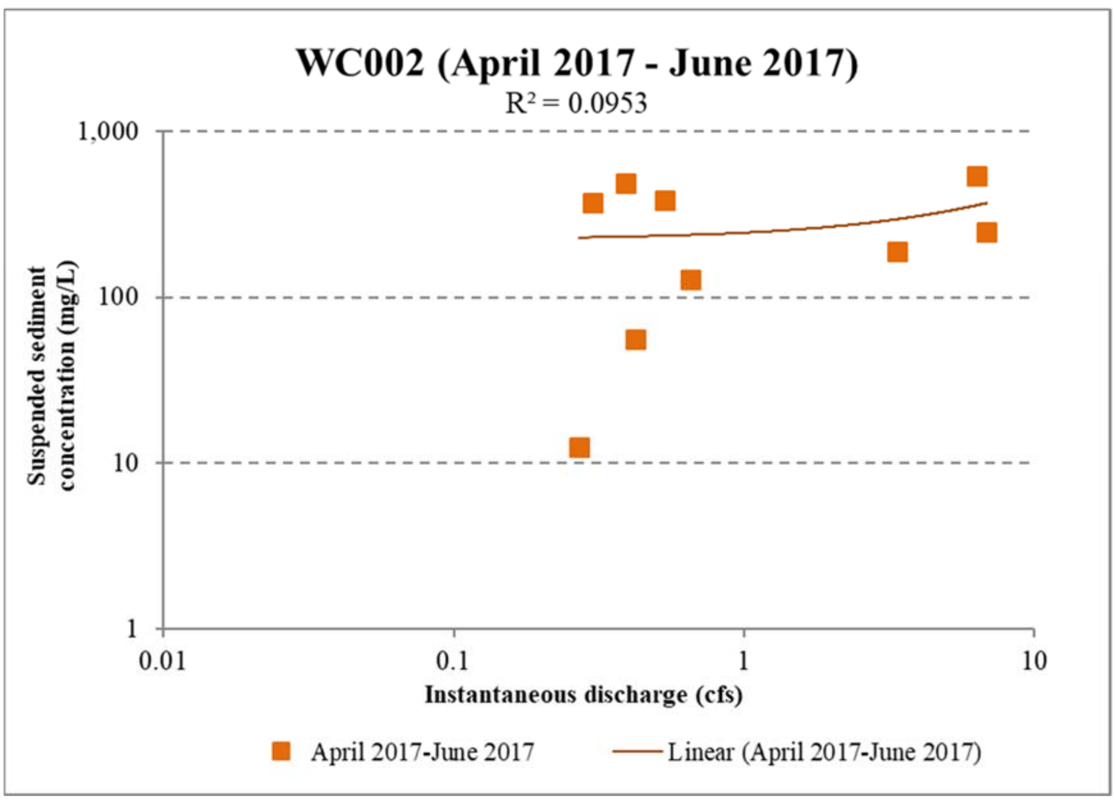

Figure 4-17. Suspended sediment curve for Wheel Creek Station 002 (April 2017-June 2017)

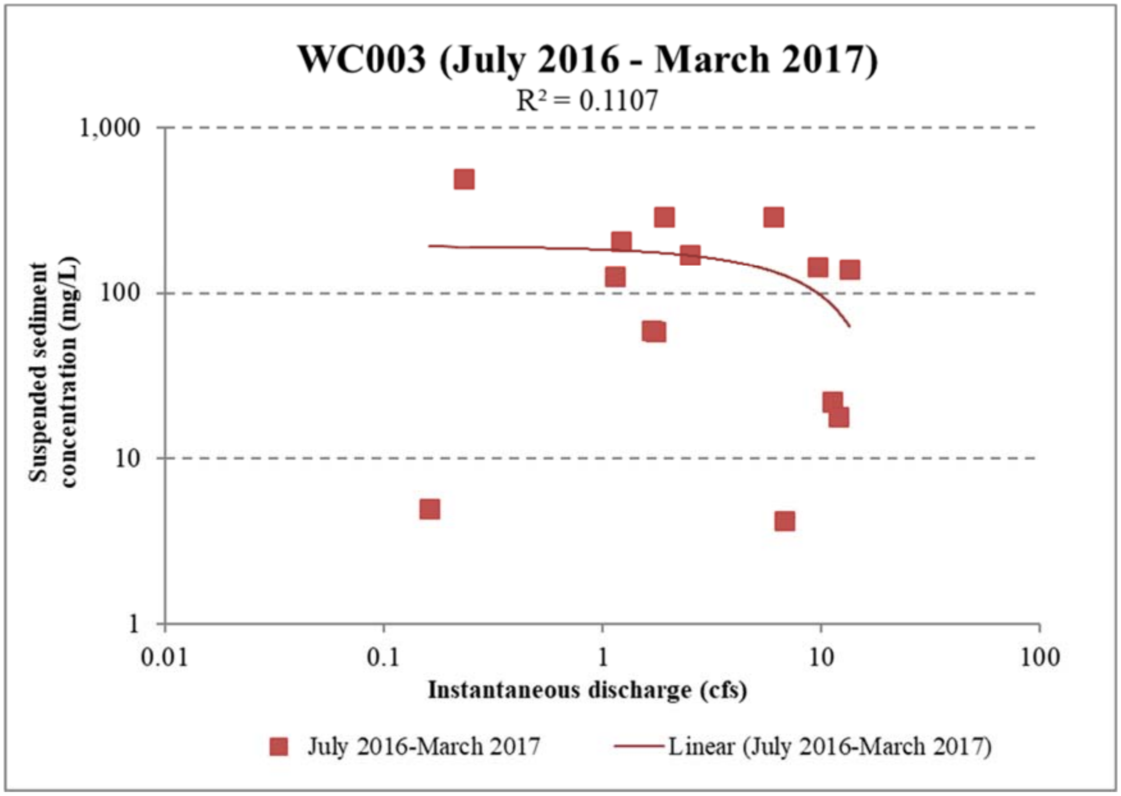

Figure 4-18. Suspended sediment curve for Wheel Creek Station 003 (July 2016-March 2017)

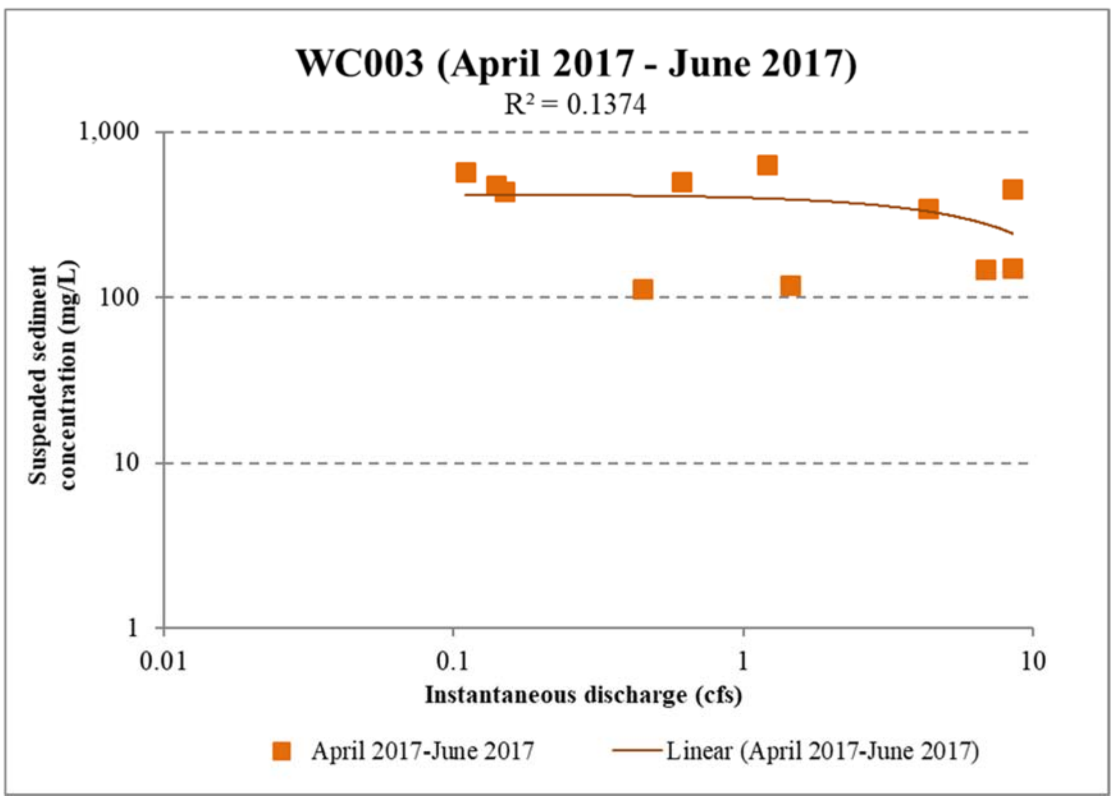

Figure 4-19. Suspended sediment curve for Wheel Creek Station 003 (April 2017-June 2017)

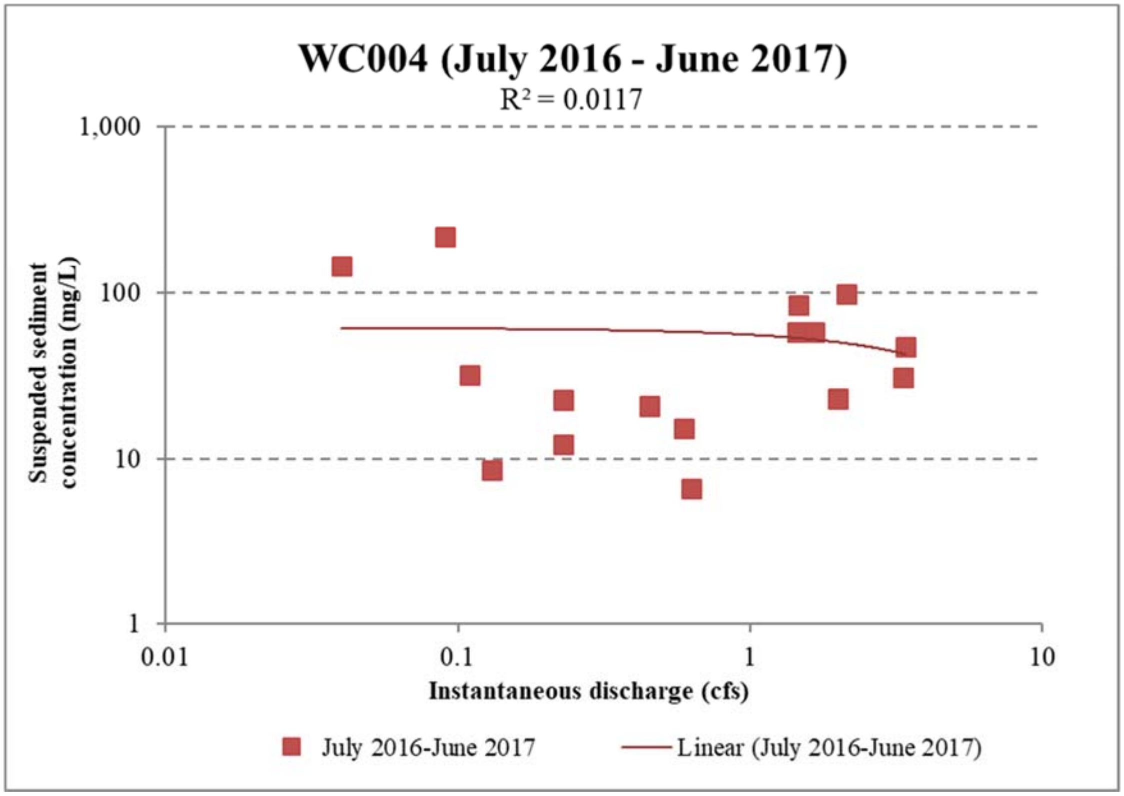

Figure 4-20. Suspended sediment curve for Wheel Creek Station 004 (July 2016-June 2017)

4.7 MONITORING PROBLEMS IDENTIFIED IN 2016-2017

4.7.1 Storm Events

During the August 17-18, 2016 storm event, the ISCO flowmeter failed at Station WC004. To approximate discharge during the storm event for composite samples, the Solinst level logger and barometric logger were briefly removed and downloaded to create a hydrograph.

During the September 19-20, 2016 storm event, the Wheel Creek Rain Gauge was found to have dirt inside the funnel and the top of the gauge had been removed and placed upside down. Staff suspect that the gauge was struck during construction. No important data were lost or compromised by this occurrence.

During the November 29, 2016 storm event, the ISCO flowmeter failed at Station WC004. The hydrograph and proportions of discrete samples from Station WC003 were used for preparation of the composite samples. The ISCO flowmeter problem was traced to a faulty battery connection cable that has since been replaced.

During the December 6-7, 2016 storm event, the area-velocity probe at Station WC002 was blocked by debris around the peak of the event. The discharges were estimated using the USGS Wheel Creek flow gauging station for the affected intervals.

On January 22, 2017 and February 28, 2017, the Sigma sampler at Station WC002 over-sampled volumes causing bottles to overflow and mix. The Sigma sampler at Station WC002 was sent to the manufacturer for maintenance and a replacement sampler was installed.

During the March 31, 2017 storm event, the area-velocity probe at Station WC002 experienced a debris block at approximately the peak of the storm. The missing data were estimated using the USGS Wheel Creek station for the affected intervals. Also, the siphon sampler at Station WC002 was damaged by the high flows and accumulation of debris, but all samples were intact and submitted.

During the June 19-20, 2017 storm event, the area-velocity probe at Station WC003 experienced a debris block during the rising and peak limb of the storm. The hydrograph from Station WC004 was used to identify discrete samples and aliquot amounts to prepare composite samples for both Stations WC004 and WC003.

The area-velocity probe at Station WC002 detached from its bracket in the culvert due to high flows. Flow rate data from the USGS Wheel Creek gauging station were used to composite samples.

4.7.2 Continuous Flow Logging

For the 2016-2017 reporting period and moving forward, Versar has assumed responsibility for the continuous discharge monitoring previously conducted by DNR. The Solinst level loggers at each station were downloaded monthly. Episodes of sensor drift due to sediment after storm flows and leaf debris in the fall have been noted. Adjustments to correct for the drift and leaf buildup were performed to improve the flow record.

In the winter months, there were several short periods when the Solinst level loggers were removed from the stream due to cold weather and risk of damage to sensors from ice buildup. To reduce data gaps, ISCO flowmeters were installed at each site when the Solinst instruments were temporarily removed.

Flow logging at Station WC003 was offline due to construction in early 2017. No storms were attempted at this station from January through April. The Solinst level logger was removed from this station during the cold weather period described above and for the entire period of construction to avoid damage to the logger from sediment or construction equipment. An ISCO flowmeter was temporarily installed to minimize the data gap in the absence of the level logger. The data collected during this time were determined to be inaccurate due to the alteration of flow during construction. Because of these missing flow data, the seasonal load for Winter 2017 at Station WC003 was not calculated.

5.0 CONCLUSIONS

In a cooperative effort, Harford County DPW, Versar, and USGS conducted water chemistry and long-term flow monitoring in the Wheel Creek watershed from July 1, 2016 through June 30, 2017. The monitoring effort included monthly baseflow sampling, nine wet weather sampling events with suspended sediment transport sampling, and synoptic sampling. Baseflow and stormflow monitoring consisted of sampling for suspended solids, copper, lead, zinc, BOD, ammonia, nitrate plus nitrite, dissolved nitrate plus nitrite, chloride, orthophosphate, total phosphorous, dissolved total phosphorous, TKN, dissolved TKN, turbidity, hardness, TPH, and *E. coli*. Synoptic sampling consisted of monitoring for nitrate plus nitrite and orthophosphate in both the Wheel Creek watershed and a reference watershed.

5.1 SUMMARY OF MONITORING RESULTS

Federal and State reference values for certain nutrients were exceeded on several occasions, confirming detrimental stream chemistry impacts from development and changes in land use. Total nitrogen, calculated from the sum of nitrate plus nitrite and TKN, was present at concentrations exceeding the EPA reference values (0.69 mg/L) for both baseflow (100% of all detected samples) and stormflow (98.6% of detected samples). The frequencies of detection represented an increase from the previous monitoring period where 94.3% of baseflow samples and 93.5% of stormflow samples were above EPA reference concentrations. Conversely, 13.9% of baseflow samples and 86.6% of stormflow samples containing detectable total phosphorus were found to be above the corresponding EPA reference concentration (0.03656 mg/L), down from 33.3% and 90.8%, respectively, in the previous monitoring period. No stormflow samples exceeded the EPA acute criterion for chloride (860 mg/L), while 41.7% of baseflow samples exceeded the chronic criterion for chloride (230 mg/L).

All baseflow samples had detectable amounts of zinc but none exceeded the MDE chronic surface water criterion (120 µg/L). All stormflow samples had detectable concentrations of zinc and three samples had amounts exceeding the MDE acute criterion (120 µg/L). All lead concentrations fell below the MDE acute criterion (65 µg/L) for stormflow and the chronic criterion (2.5 µg/L) for baseflow this monitoring period. Copper concentrations did not exceed the MDE chronic criterion (9 µg/L) in baseflow samples, while 18.8% of stormflow samples exceeded the acute criterion (13 µg/L).

E. coli bacteria concentrations were detected in all baseflow samples at all stations, ranging in concentration from 2.0 to greater than the maximum reporting limit of 2,420 MPN/100ml. Only one sample, taken at Station WC002 on 9/27/2016, exceeded the maximum reporting limit during baseflow. *E. coli* concentrations were equal to or above the maximum reportable result in 50% of stormflow grab samples, up from 40% in the 2015-2016 monitoring period. TPH was not detected above the reporting limit in any of the baseflow or stormflow grab samples collected at the monitoring stations.

Average baseflow concentrations of combined nitrate plus nitrite, hardness, and *E. coli* were highest at Station WC004 compared to the other two stations downstream. Samples collected at Station WC003 had the highest average concentrations of total phosphorus, TPH, TSS, TKN, zinc, lead, and ammonia during baseflow conditions. Station WC002 samples had the highest average concentrations of BOD at baseflow. Average stormflow EMCs were highest at Station WC004 for lead and zinc only. The average EMC for TPH was highest at Station WC002. Average EMCs for remaining parameters, including BOD, hardness, ammonia, nitrate plus nitrite, TKN, phosphorus, TSS, copper, and *E. coli* were highest at Station WC003. These results were impacted by the last two storm events of the monitoring period in May and June after completion of the wet pond and culvert retrofit just upstream of the station. During these two storm events, results indicated a noticeable spike in concentrations of BOD, ammonia, TKN, TSS, and all metals. These parameters may have been carried by suspended solids in stormflow that may have been liberated by the conclusion of construction activity.

Average stormflow loads were highest at WC002 for all parameters except ammonia, which was highest at Station WC003. Average loads were lowest at WC004 for all parameters. Since discharge volume for a given storm increases with distance downstream, maximum load results at Station WC002 are expected.

Nutrient synoptic sampling in Wheel Creek in 2017 continued to identify a combined nitrate plus nitrite hotspot, near Station WC004, with concentrations in the moderate category. The nitrate plus nitrite result at Station W8, just downstream of Station WC004, had the highest nitrate/ nitrite concentration of all indicator stations surveyed in the current period, and was in the high category during the previous two periods. Stations W4 and W6, both located in upstream catchments, had nitrate plus nitrite concentrations consistently in the moderate category from 2015-2017. Concentrations in downstream catchments, such as Stations W1, W3, and W5 fluctuated between baseline and moderate conditions during the past three years. The nitrate plus nitrite yield at Station W4 decreased from the excessive to baseline category, largely because of a decrease in discharge at that location. In the reference watershed, nitrate plus nitrite concentrations at all stations decreased from the prior monitoring period and fell into the baseline category. All nitrate plus nitrite yields in the reference watershed were also baseline. All stations in both the Wheel Creek and reference watersheds had non-detectable amounts of orthophosphate except for Station W5 which was in the excessive category. It is important to note that the lab had a detection limit of 0.05 mg/L for orthophosphate and anything testing above that limit would therefore be excessive in concentration. Orthophosphate yields were baseline at all indicator and reference stations in 2015 and 2016. In 2017, the orthophosphate yield at Station W5 was in the high category, because of the 0.06 mg/L result and the higher discharge compared to 2016.

Suspended sediment transport correlated well with discharge at Station WC002 before the completion of the wet pond upstream of Station WC003. As in past monitoring periods, the sediment results have correlated better with discharge at the station having the largest contributing watershed area. In the current monitoring period, there was no correlation established between sediment and discharge at Stations WC003 and WC004.

5.2 SUMMARY OF WATERSHED IMPACTS

Results of water chemistry monitoring conducted in the 2016-2017 period demonstrated:

- watershed-wide effects,
- concentrated impacts from highly impervious areas,
- the presence of a nutrient and bacteria source just downstream of the Festival Shopping Center,
- elevated suspended sediment and pollutant levels at Station WC003, downstream of the Pond E facility, immediately after retrofit construction, and,
- reduction of average annual storm EMCs for several pollutants at Station WC002 from the previous monitoring period, providing an early indication of positive effects of the cumulative watershed restoration efforts.

Federal guidelines for nutrient pollution (in the form of total nitrogen and total phosphorus) were routinely exceeded throughout the watershed during baseflow and stormflow for total nitrogen and stormflow for total phosphorus. For metals, state criteria were exceeded for isolated copper and zinc results. Urban pollutants such as zinc and *E. coli* were present in all samples during both baseflow and stormflow conditions. Maximum average storm loads in the watershed were found at Station WC002 (downstream) for all pollutants except ammonia, which provides a gauge of overall watershed impact from development, including pollutant input from highly utilized roadways, commercial enterprises, and ongoing erosion.

Results of monitoring at Station WC004 document the downstream impact of stormwater runoff from commercial land use at Festival Shopping Center. Average annual stormflow concentrations were highest at Station WC004 for zinc and lead, which indicate continued impact to the waterway from the parking areas and roadway in the drainage. The average annual EMC for zinc also increased from the prior period level. At Station WC004, annual average baseflow concentrations of combined nitrate plus nitrite, and *E. coli* were highest. Similarly, combined nitrate plus nitrite concentrations were the highest in Wheel Creek watershed at the nearby Station W8 during annual synoptic nutrient monitoring in 2017. Both data sets indicate an ongoing chronic problem with nutrient and bacteria input into these headwaters.

Included in the restoration construction schedule during the monitoring period (July 2016 to June 2017) were the lower Wheel Creek stream restoration (September 2016 – March 2017), and the Pond E water quality facility retrofit (December 2016 – April 2017). With the completion of these restoration activities, the overall restoration of Wheel Creek watershed is complete and a rigorous evaluation of the watershed-wide BMPs can begin. Individual performance measures to compare pre-restoration to post-restoration conditions may include: evaluation of peak storm flows, average annual concentrations, average annual loads, storm loads or sediment transport.

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6.0 REFERENCES

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APPENDIX A

STORM EVENT SUMMARY REPORTS

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WHEEL CREEK STORM MONITORING SUMMARY REPORT

AUGUST 17-18, 2016

INTRODUCTION

On August 17 and 18, Versar conducted storm monitoring at the Wheel Creek stations. Samples were successfully collected at Stations WC002, WC003, and WC004 using the Sigma 900Max automated samplers. This report presents water chemistry results for this event.

Site locations are as follows:

- Station WC004: Located on north side of Wheel Court. Level logger is located downstream of storm shelter.
- Station WC003: Located on south side of Cinnabar Lane, west of Wheel Road. Flow sensor is located within outfall pipe.
- Station WC002: Located on south side of Wheel Road, just west of junction of Arthurs Woods Drive. Flow sensor is located within culvert.

RESULTS

Versar field staff traveled to the site on August 17 to deploy siphon samplers and program the Sigma automated samplers to sample the event. Rainfall initiated at approximately 9:30 p.m. the night of August 17. A rainfall total of 0.46 inches was recorded at the Wheel Creek Rain Gauge Station.

On the morning of August 18, field staff collected grab water samples to be tested for TPH and *E. coli* at each station that coincided with the falling limb of the storm. The *E. coli* samples were submitted to Enviro-Chem Laboratories for analysis shortly after collection.

Field staff traveled to the sites on August 19 to composite automated and suspended sediment samples (SSC). SSC siphon samples were submitted to the laboratory for analysis on August 22. Composite and TPH samples were transported and submitted directly to Eurofins QC on August 19th.

Hydrographs for the August 17-18 storm are presented in Figure 1 through Figure 3 below. Laboratory analytical and field water quality results for the August 17-18 storm are shown in Table 1 through Table 4. Rainfall and flow statistics for the event are shown in Table 5.

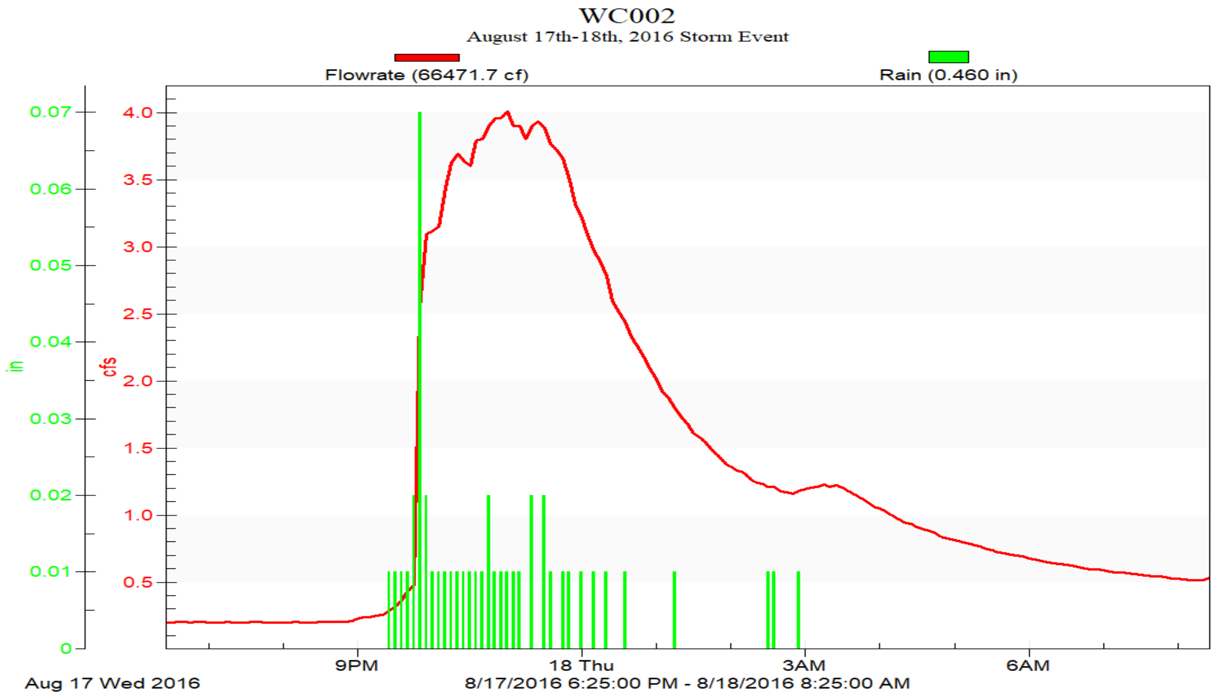

Figure 1. Hydrograph at Station WC002 for August 17-18, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

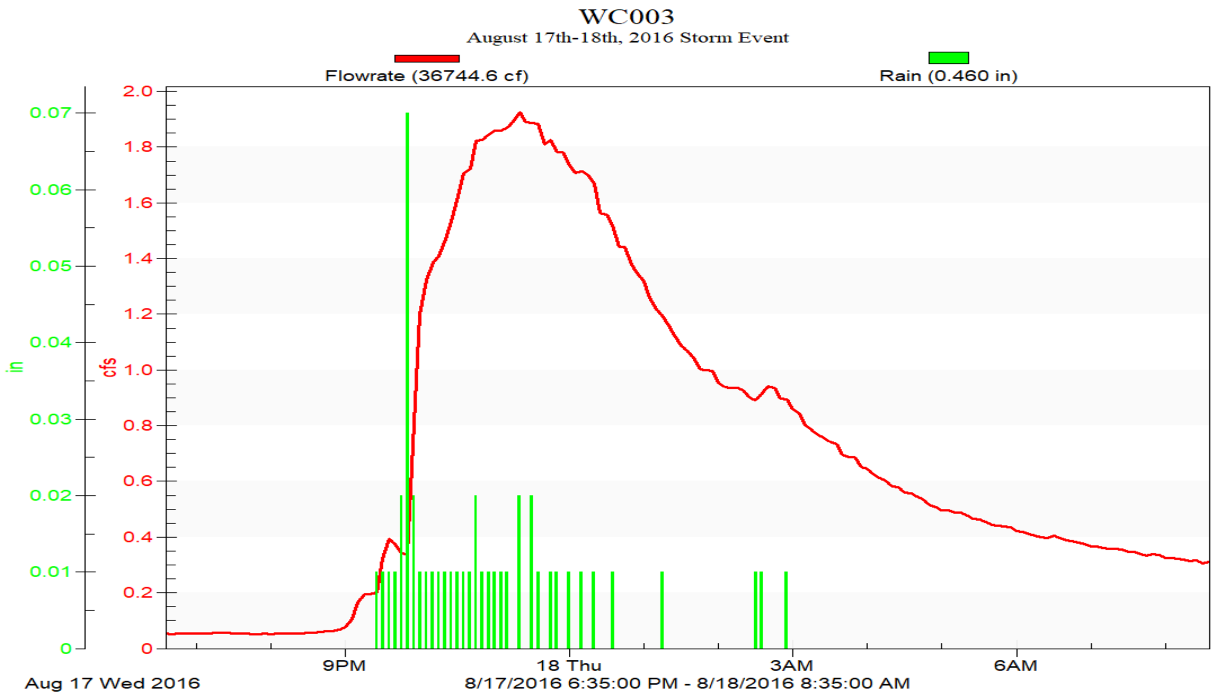

Figure 2. Hydrograph at Station WC003 for August 17-18, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

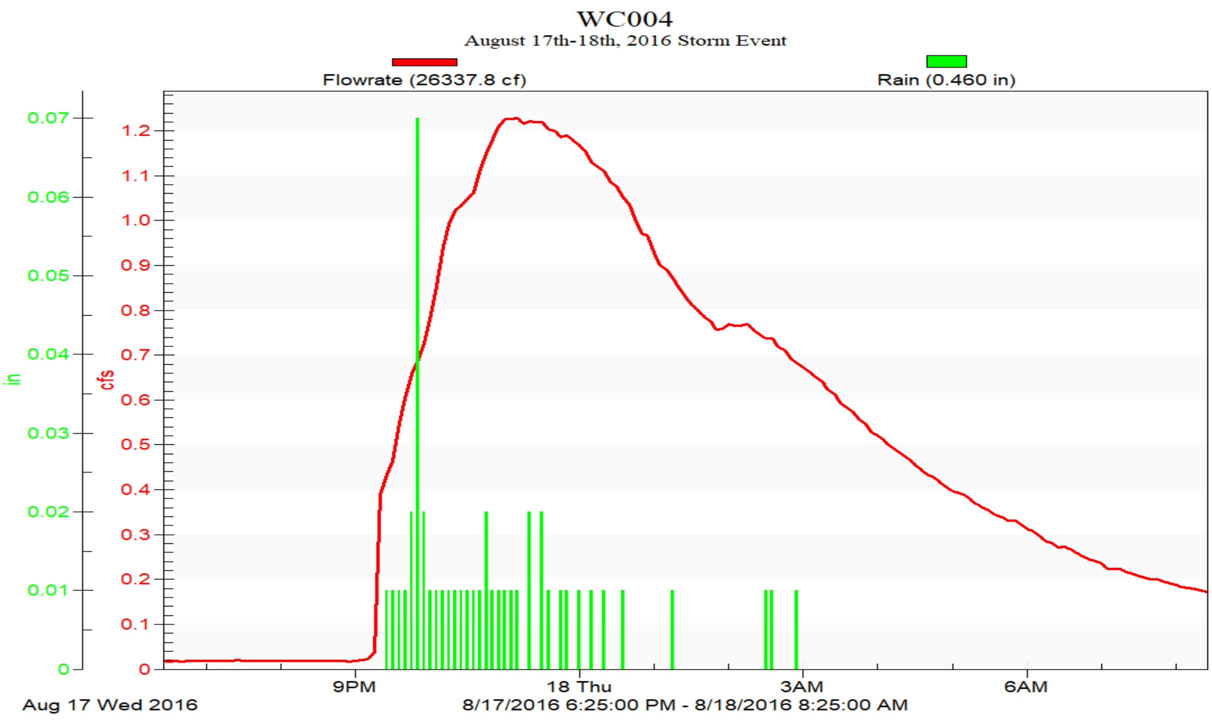

Figure 3. Hydrograph at Station WC004 for August 17-18, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

Table 1. Analytical results – Wheel Creek automated sampling, Rising Limb

Constituent	17/18-Aug-16		
	Station WC002 (mg/L)	Station WC003 (mg/L)	Station WC004 (mg/L)
5-Day BOD	7	7	8
Nitrate Nitrogen	1	0.758	0.579
Nitrate-Nitrite Nitrogen	1	0.758	0.579
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	41	72.5	59.2
Copper	0.0054	0.0124	0.0212
Lead	< 0.015	< 0.015	< 0.015
Zinc	0.0199	0.0303	0.0477
Chloride	64.9	45.1	25.3
Ammonia Nitrogen	0.194	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	0.886	0.786	1.05
Total Phosphorus	0.111	0.127	0.151
pH	7.67	7.13	7.12

Table 2. Analytical results – Wheel Creek automated sampling, Peak Limb

Constituent	17/18-Aug-16 Station WC002 (mg/L)	Station WC003 (mg/L)	Station WC004 (mg/L)
5-Day BOD	6	7	5
Nitrate Nitrogen	0.663	0.572	0.506
Nitrate-Nitrite Nitrogen	0.663	0.572	0.506
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	15.6	27.2	11.2
Copper	< 0.01	0.0095	0.0103
Lead	< 0.015	< 0.015	< 0.015
Zinc	0.012	0.0182	0.0193
Chloride	26.7	30.5	18.8
Ammonia Nitrogen	0.178	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	0.47	0.631	0.606
Total Phosphorus	0.0732	0.0773	0.0773
pH	7.66	7.12	6.94

Table 3. Analytical results – Wheel Creek automated sampling, Falling Limb

Constituent	17/18-Aug-16 Station WC002 (mg/L)	Station WC003 (mg/L)	Station WC004 (mg/L)
5-Day BOD	4	5	<2
Nitrate Nitrogen	0.683	0.601	0.613
Nitrate-Nitrite Nitrogen	1.02	0.601	0.613
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	5.2	16.8	4
Copper	0.0047	0.0053	0.0055
Lead	< 0.015	< 0.015	< 0.015
Zinc	0.0084	0.0127	0.0138
Chloride	30.1	37	21.9
Ammonia Nitrogen	< 0.2	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	0.455	0.286	0.295
Total Phosphorus	0.0536	0.0493	0.0409
pH	7.36	6.98	6.75

Table 4. Analytical Results – Wheel Creek Grab Sampling

Constituent	Station WC002	Station WC003	Station WC004
August 18, 2016 (Falling)			
TPH (mg/L)	< 5	< 5	< 5
E. coli (MPN/100 ml)	1990	1120	613
Temp (C)	22.5	22.3	22.8
DO (mg/L)	7.79	7.75	7.48
pH	7.95	7.66	7.62
Sp. Cond. (mS/cm)	0.178	0.177	0.107

Table 5. Rainfall and flow statistics

Constituent	Station WC002	Station WC003	Station WC004
Rainfall (in.)	0.46	0.46	0.46
Duration (hrs.)	24	24	23
Intensity (in./hr.)	0.0192	0.0192	0.02
Discharge Volume (ft^3)	80,401	43,812	29,104

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VERSAR

WHEEL CREEK STORM MONITORING
SUMMARY REPORT
SEPTEMBER 19-20, 2016

INTRODUCTION

On September 19 and 20, Versar conducted storm monitoring at the Wheel Creek stations. Samples were successfully collected at Stations WC002, WC003, and WC004 using the Sigma 900Max automated samplers. This report presents water chemistry results for this event.

Site locations are as follows:

- Station WC004: Located on north side of Wheel Court. Level logger is located downstream of storm shelter.
- Station WC003: Located on south side of Cinnabar Lane, west of Wheel Road. Flow sensor is located within outfall pipe.
- Station WC002: Located on south side of Wheel Road, just west of junction of Arthurs Woods Drive. Flow sensor is located within culvert.

RESULTS

Versar field staff traveled to the site on September 18 to deploy siphon samplers and program the Sigma automated samplers to sample the event. Rainfall initiated at approximately 5:25 a.m. the morning of September 19. A rainfall total of 0.75 inches was recorded at the Wheel Creek Rain Gauge Station.

On the morning of September 19, field staff collected grab water samples to be tested for TPH and *E. coli* at each station shortly after rainfall began during the first flush. The *E. coli* samples were submitted to Enviro-Chem Laboratories for analysis after collection.

Field staff traveled to the sites on September 20 to composite automated and suspended sediment samples (SSC). SSC siphon samples were submitted to the laboratory for analysis on September 22. Composite and TPH samples were transported to the Harford County government offices to await pickup by Eurofins QC on September 20.

Hydrographs for the September 19-20 storm are presented in Figure 1 through Figure 3 below. Laboratory analytical and field water quality results for the September 19-20 storm are shown in Table 1 through Table 4. Rainfall and flow statistics for the event are shown in Table 5.

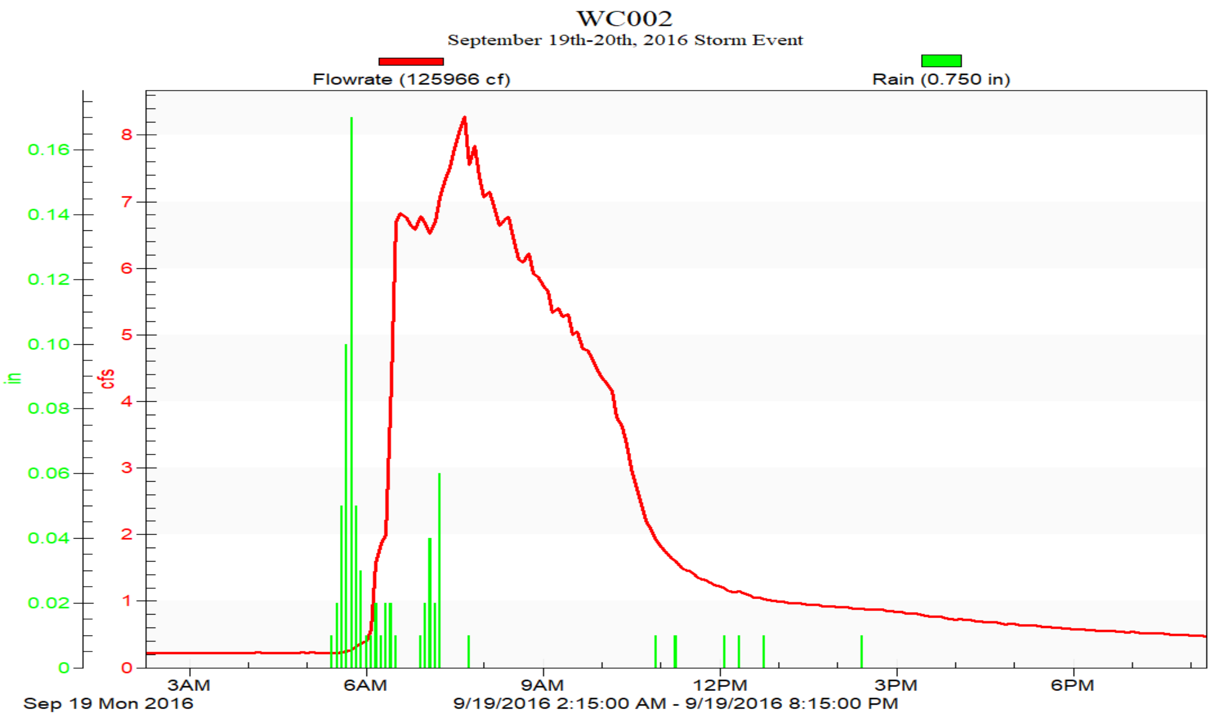

Figure 1. Hydrograph at Station WC002 for September 19-20, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

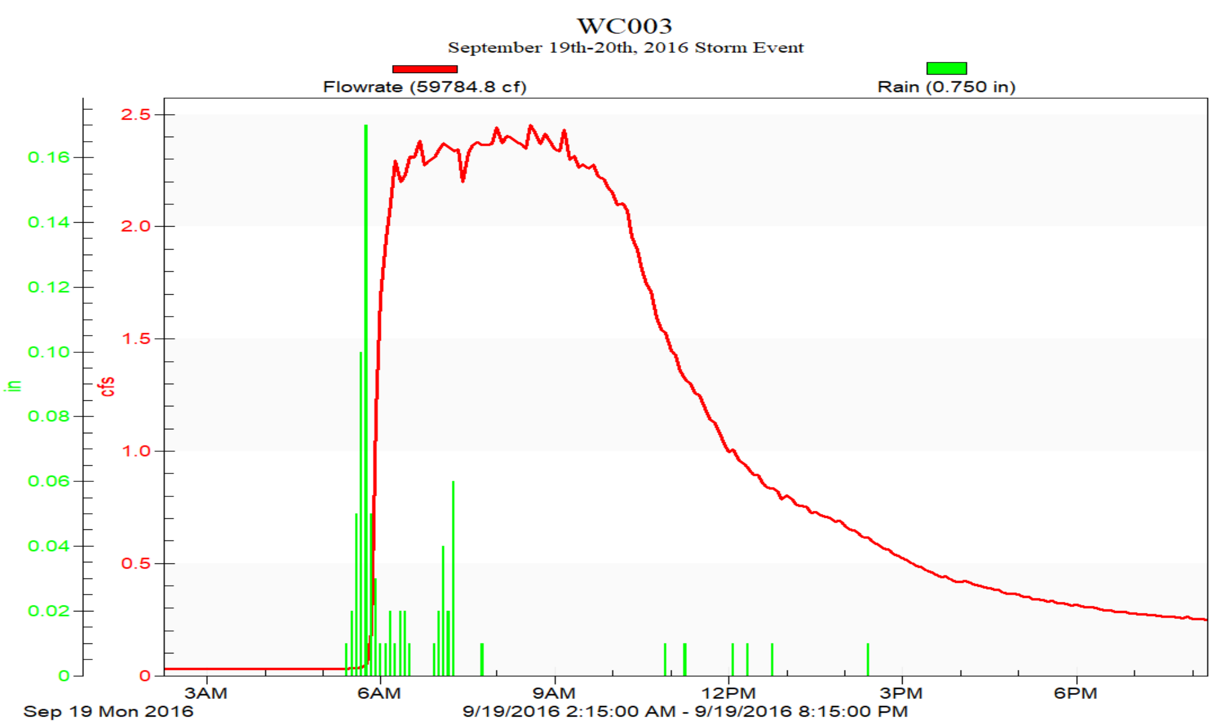

Figure 2. Hydrograph at Station WC003 for September 19-20, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

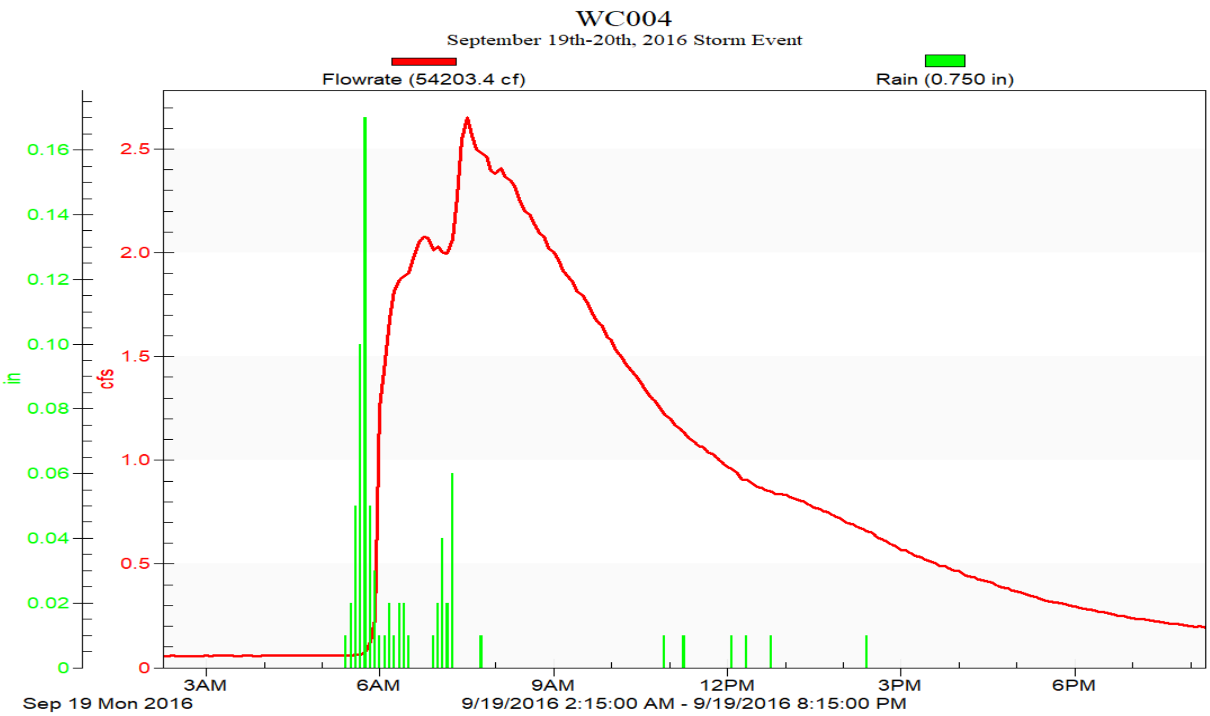

Figure 3. Hydrograph at Station WC004 for September 19-20, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

Table 1. Analytical results – Wheel Creek automated sampling, Rising Limb

Constituent	19/20-Sep-16 Station WC002 (mg/L)	19/20-Sep-16 Station WC003 (mg/L)	19/20-Sep-16 Station WC004 (mg/L)
5-Day BOD	9	17	5
Nitrate Nitrogen	1.82	1.53	3.75
Nitrate-Nitrite Nitrogen	1.82	1.53	3.75
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	54.2	210	24.4
Copper	0.0064	0.0166	0.0062
Lead	< 0.015	< 0.015	< 0.015
Zinc	0.0342	0.0916	0.0338
Chloride	97	150	193
Ammonia Nitrogen	< 0.2	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	0.739	1.86	0.5
Total Phosphorus	0.141	0.426	0.0856
pH	7.23	7.16	7.26

Table 2. Analytical results – Wheel Creek automated sampling, Peak Limb			
Constituent	**19/20-Sep-16**		
	Station WC002 (mg/L)	**Station WC003 (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	15	11	7
Nitrate Nitrogen	0.983	0.843	0.858
Nitrate-Nitrite Nitrogen	0.983	0.843	0.858
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	57	35.2	11.4
Copper	0.0099	0.0101	0.0073
Lead	< 0.015	< 0.015	< 0.015
Zinc	0.032	0.0306	0.0203
Chloride	35.8	34.1	18.2
Ammonia Nitrogen	< 0.2	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	1.13	0.744	0.779
Total Phosphorus	0.2	0.106	0.0902
pH	7.35	7.31	7.53

Table 3. Analytical results – Wheel Creek automated sampling, Falling Limb			
Constituent	**19/20-Sep-16**		
	Station WC002 (mg/L)	**Station WC003 (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	10	7	10
Nitrate Nitrogen	0.935	0.932	0.639
Nitrate-Nitrite Nitrogen	0.935	0.932	0.639
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	7.6	14.4	6
Copper	0.0048	0.006	0.0071
Lead	< 0.015	< 0.015	< 0.015
Zinc	0.0089	0.0165	0.0243
Chloride	33.6	34.9	20.9
Ammonia Nitrogen	< 0.2	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	0.554	0.699	0.847
Total Phosphorus	0.0622	0.0681	0.084
pH	7.32	7.24	7.28

Table 4. Analytical Results – Wheel Creek Grab Sampling

Constituent	Station WC002	Station WC003	Station WC004
September 19, 2016 (Rising)			
TPH (mg/L)	2.1	< 5	< 5
E. coli (MPN/100 ml)	> 2420	> 2420	> 2420
Temp (C)	23.2	22.0	22.0
DO (mg/L)	7.99	8.07	7.84
pH	7.31	7.15	7.28
Sp. Cond. (mS/cm)	0.088	0.212	0.216

Table 5. Rainfall and flow statistics

Constituent	Station WC002	Station WC003	Station WC004
Rainfall (in.)	0.75	0.75	0.75
Duration (hrs.)	28	36	26
Intensity (in./hr.)	0.0268	0.0208	0.0288
Discharge Volume (ft^3)	137,914	71,327	57,724

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WHEEL CREEK STORM MONITORING
SUMMARY REPORT
NOVEMBER 29, 2016

INTRODUCTION

On November 29, Versar conducted storm monitoring at the Wheel Creek stations. Samples were successfully collected at Stations WC002, WC003, and WC004 using the Sigma 900Max automated samplers. This report presents water chemistry results for this event.

Site locations are as follows:

- Station WC004: Located on north side of Wheel Court. Level logger is located downstream of storm shelter.
- Station WC003: Located on south side of Cinnabar Lane, west of Wheel Road. Flow sensor is located within outfall pipe.
- Station WC002: Located on south side of Wheel Road, just west of junction of Arthurs Woods Drive. Flow sensor is located within culvert.

RESULTS

Versar field staff traveled to the site on November 28 to deploy siphon samplers and program the Sigma automated samplers to sample the event. Rainfall initiated at approximately 5:10 a.m. the morning of November 29. A rainfall total of 0.96 inches was recorded at the Wheel Creek Rain Gauge Station.

On the morning of November 29, field staff collected grab water samples to be tested for TPH and *E. coli* at each station shortly after rainfall began during the rising limb of the storm event. The *E. coli* samples were submitted to Enviro-Chem Laboratories for analysis after collection.

Field staff traveled to the sites on December 1 to composite automated and suspended sediment samples (SSC). SSC siphon samples were submitted to the laboratory for analysis on December 1. Composite and TPH samples were transported to the Harford County government offices to await pickup by Eurofins QC on December 1.

Hydrographs for the November 29 storm are presented in Figure 1 through Figure 3 below. Laboratory analytical and field water quality results for the November 29 storm are shown in Table 1 through Table 4. Rainfall and flow statistics for the event are shown in Table 5.

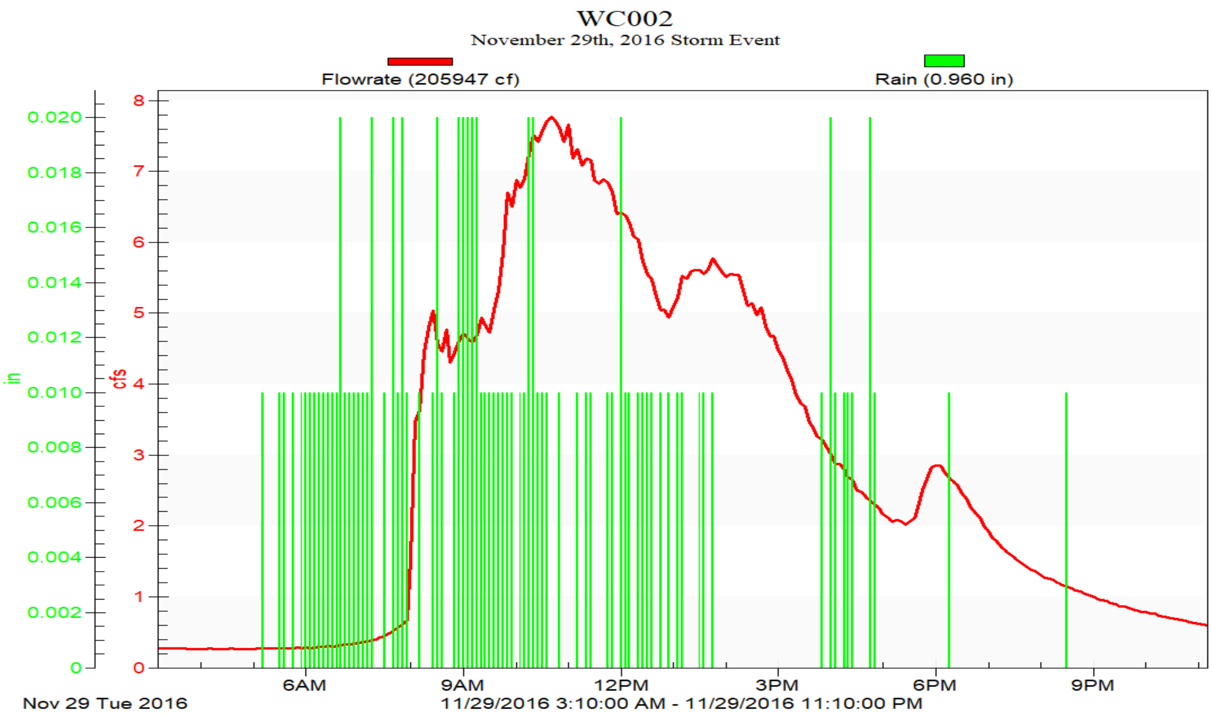

Figure 1. Hydrograph at Station WC002 for November 29, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

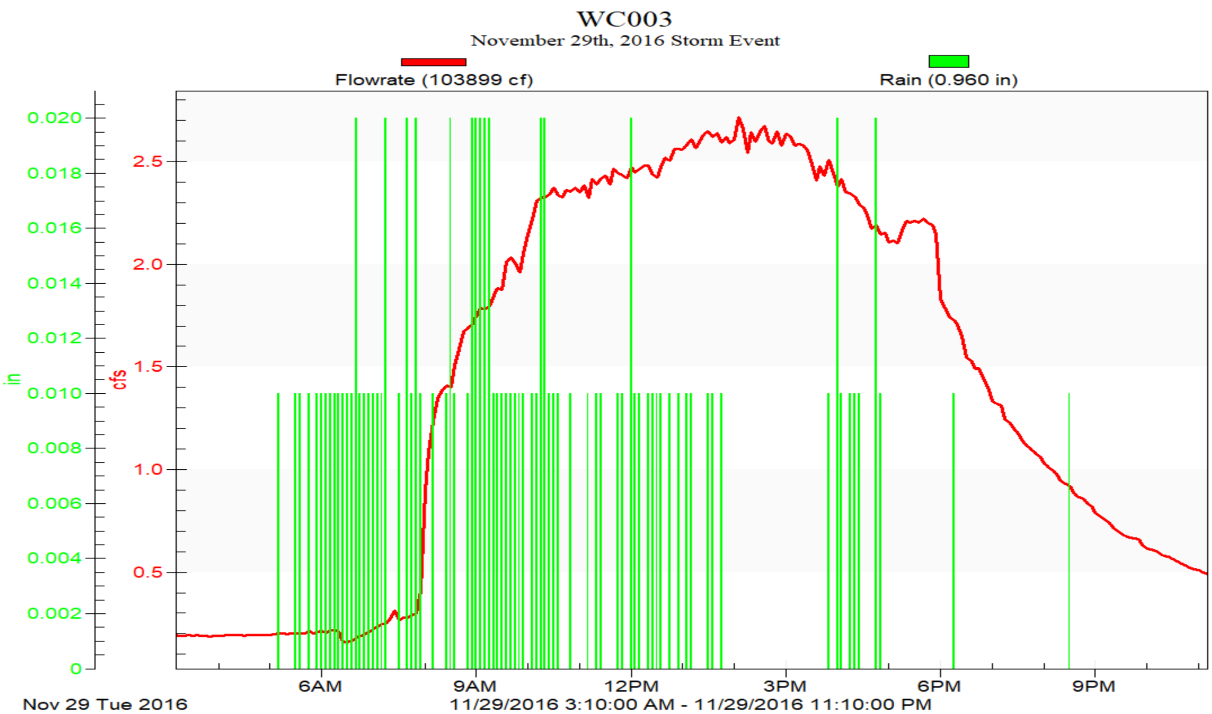

Figure 2. Hydrograph at Station WC003 for November 29, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

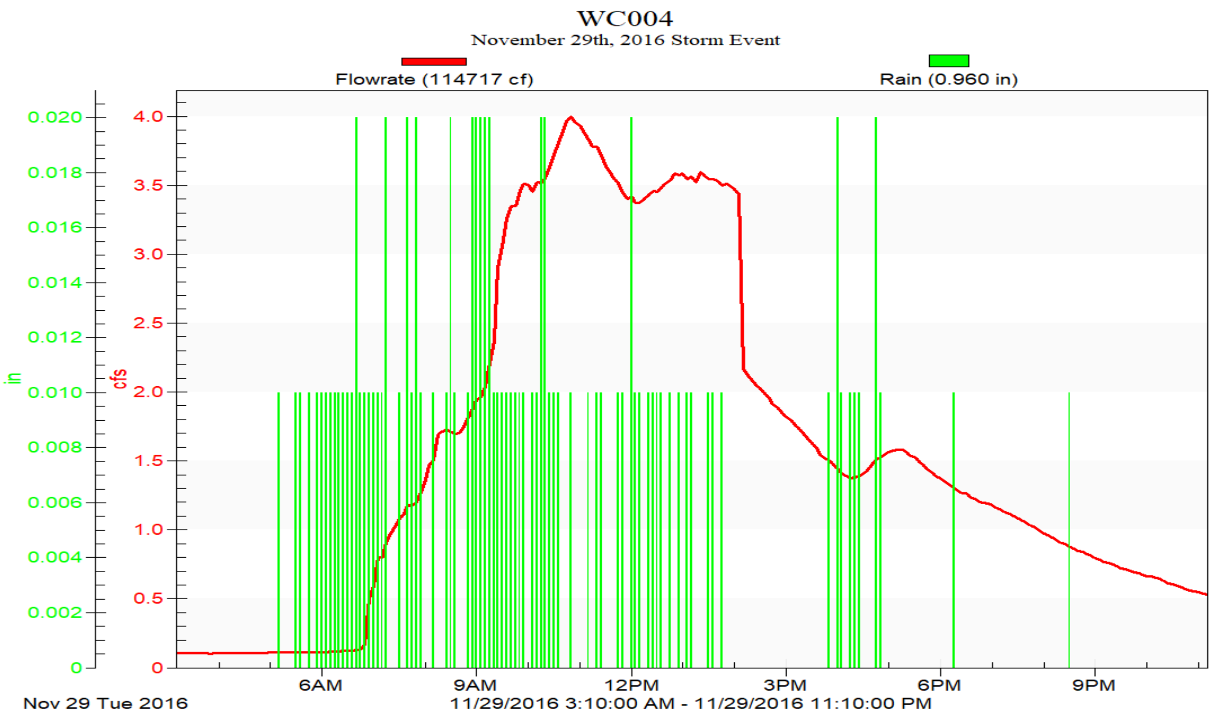

Figure 3. Hydrograph at Station WC004 for November 29, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

Table 1. Analytical results – Wheel Creek automated sampling, Rising Limb

Constituent	29-Nov-16		
	Station WC002 (mg/L)	Station WC003 (mg/L)	Station WC004 (mg/L)
5-Day BOD	18	4	7
Nitrate Nitrogen	1.79	2.56	1.07
Nitrate-Nitrite Nitrogen	1.79	2.56	1.07
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	50.8	210	68.4
Copper	0.0082	0.0225	0.0157
Lead	< 0.015	0.0082	< 0.015
Zinc	0.0424	0.141	0.0563
Chloride	121	150	36.7
Ammonia Nitrogen	< 0.2	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	1.13	2.26	1.04
Total Phosphorus	0.123	0.453	0.157
pH	7.50	7.18	7.28

Table 2. Analytical results – Wheel Creek automated sampling, Peak Limb

Constituent	29-Nov-16		
	Station WC002 (mg/L)	Station WC003 (mg/L)	Station WC004 (mg/L)
5-Day BOD	17	9	6
Nitrate Nitrogen	0.712	0.958	0.898
Nitrate-Nitrite Nitrogen	0.712	0.958	0.898
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	48	39.6	64
Copper	0.0104	0.0114	0.0173
Lead	< 0.015	< 0.015	< 0.015
Zinc	0.0401	0.0382	0.0763
Chloride	36.5	42.2	21.9
Ammonia Nitrogen	< 0.2	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	1.32	1.16	1.19
Total Phosphorus	0.18	0.122	0.159
pH	7.31	6.80	7.27

Table 3. Analytical results – Wheel Creek automated sampling, Falling Limb

Constituent	29-Nov-16		
	Station WC002 (mg/L)	Station WC003 (mg/L)	Station WC004 (mg/L)
5-Day BOD	11	18	3
Nitrate Nitrogen	0.92	0.885	0.792
Nitrate-Nitrite Nitrogen	0.92	0.885	0.792
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	5.2	12	< 4
Copper	0.0263	0.0104	0.0086
Lead	< 0.015	< 0.015	< 0.015
Zinc	0.0179	0.0246	0.027
Chloride	37.8	39.2	20.2
Ammonia Nitrogen	< 0.2	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	0.65	0.778	0.828
Total Phosphorus	0.0432	0.045	0.0344
pH	7.11	7.43	7.16

Table 4. Analytical Results – Wheel Creek Grab Sampling

Constituent	Station WC002	Station WC003	Station WC004
November 29, 2016 (Rising)			
TPH (mg/L)	< 5	< 5	< 5
E. coli (MPN/100 ml)	308	2420	> 2420
Temp (C)	8.6	8.4	9.1
DO (mg/L)	10.83	9.93	11.10
pH	7.35	6.88	7.84
Sp. Cond. (mS/cm)	0.381	0.550	0.109

Table 5. Rainfall and flow statistics

Constituent	Station WC002	Station WC003	Station WC004
Rainfall (in.)	0.96	0.96	0.96
Duration (hrs.)	24	26	26
Intensity (in./hr.)	0.04	0.0369	0.0369
Discharge Volume (ft^3)	211,847	111,430	122,255

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VERSAR

WHEEL CREEK STORM MONITORING
SUMMARY REPORT
DECEMBER 6-7, 2016

INTRODUCTION

On December 6-7, Versar conducted storm monitoring at the Wheel Creek stations. Samples were successfully collected at Stations WC002, WC003, and WC004 using the Sigma 900Max automated samplers. This report presents water chemistry results for this event.

Site locations are as follows:

- Station WC004: Located on north side of Wheel Court. Level logger is located downstream of storm shelter.
- Station WC003: Located on south side of Cinnabar Lane, west of Wheel Road. Flow sensor is located within outfall pipe.
- Station WC002: Located on south side of Wheel Road, just west of junction of Arthurs Woods Drive. Flow sensor is located within culvert.

RESULTS

Versar field staff traveled to the site on December 6 to deploy siphon samplers and program the Sigma automated samplers to sample the event. Rainfall initiated at approximately 12:20 p.m. the afternoon of December 6. A rainfall total of 0.79 inches was recorded at the Wheel Creek Rain Gauge Station.

In the afternoon of December 6, field staff collected grab water samples to be tested for TPH and *E. coli* at all three shortly after rainfall began during the rising limb of the storm event. The *E. coli* samples were submitted to Enviro-Chem Laboratories for analysis after collection.

Field staff traveled to the sites on December 7 to composite automated and suspended sediment samples (SSC). SSC siphon samples were submitted to the laboratory for analysis on December 8. Composite and TPH samples were transported to the Harford County government offices to await pickup by Eurofins QC on December 7.

Hydrographs for the December 6-7 storm are presented in Figure 1 through Figure 3 below. Laboratory analytical and field water quality results for the December 6-7 storm are shown in Table 1 through Table 4. Rainfall and flow statistics for the event are shown in Table 5.

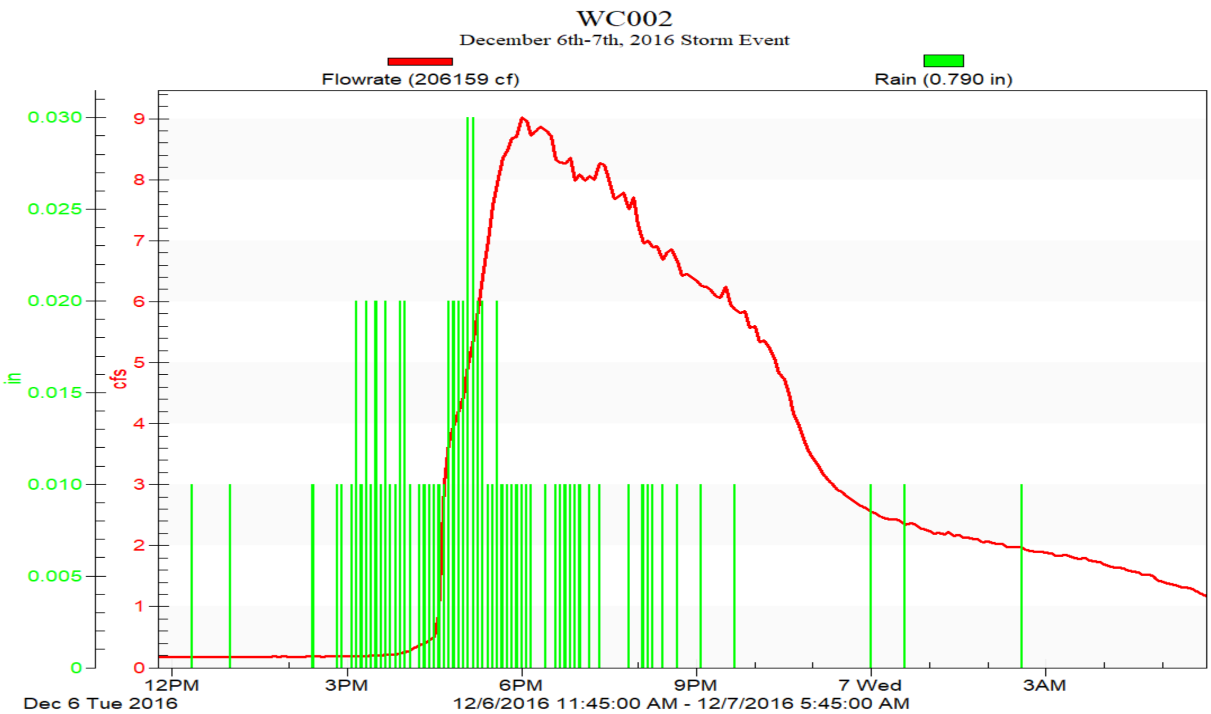

Figure 1. Hydrograph at Station WC002 for December 6-7, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

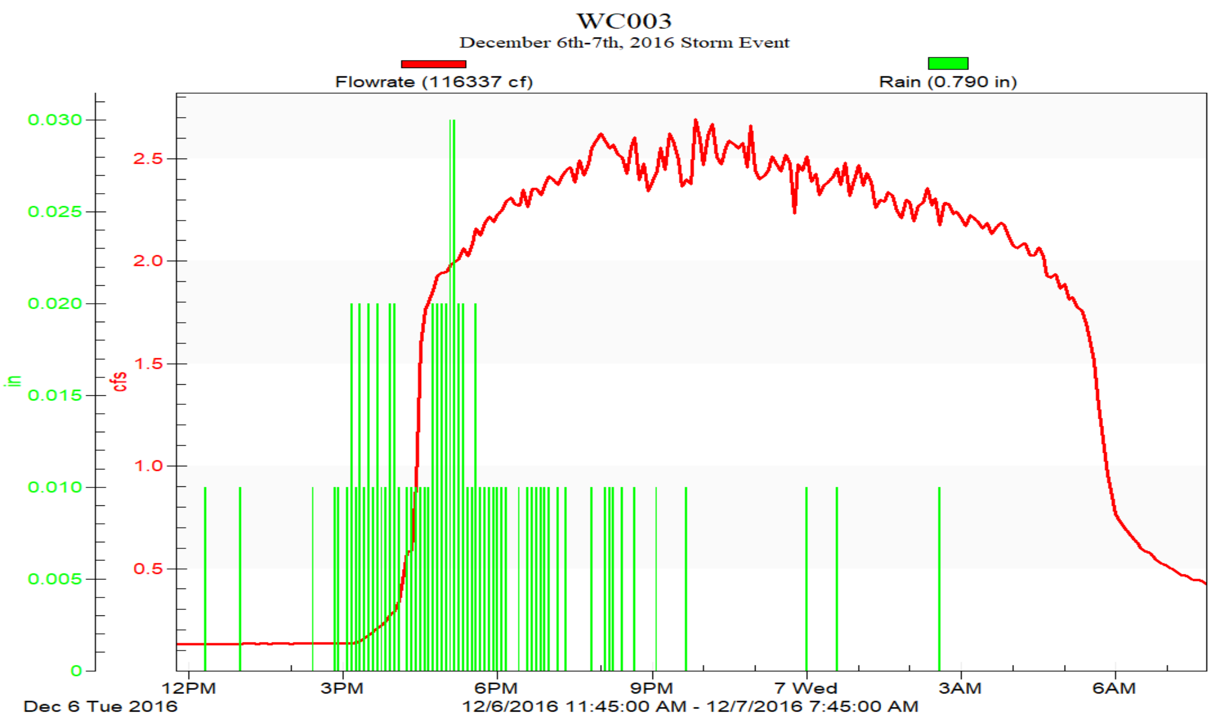

Figure 2. Hydrograph at Station WC003 for December 6-7, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

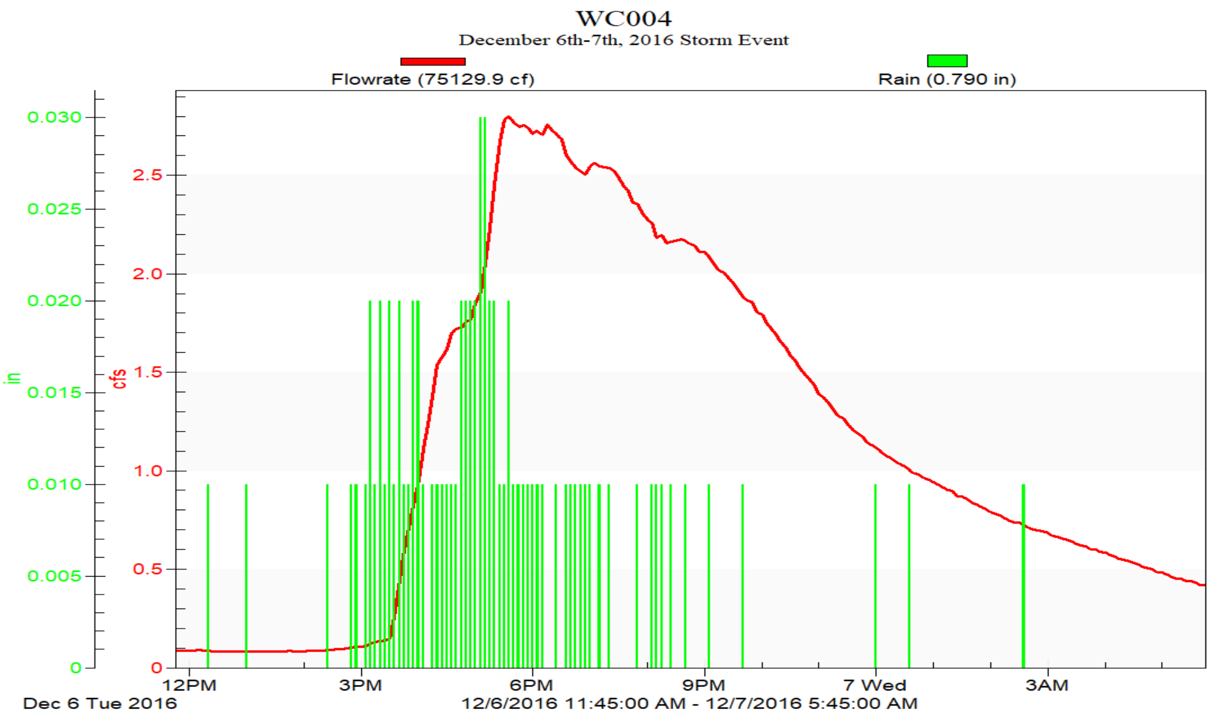

Figure 3. Hydrograph at Station WC004 for December 6-7, 2016 storm. Rainfall data source: Wheel Creek Rain Gauge Station

Table 1. Analytical results – Wheel Creek automated sampling, Rising Limb

Constituent	6/7-Dec-16		
	Station WC002 (mg/L)	Station WC003 (mg/L)	Station WC004 (mg/L)
5-Day BOD	3	3.22	3.34
Nitrate Nitrogen	1.07	0.432	0.266
Nitrate-Nitrite Nitrogen	1.07	0.432	0.266
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	17.6	34.4	64.8
Copper	<0.01	0.0052	0.012
Lead	0.0005	0.0011	0.0035
Zinc	0.0148	0.0243	0.063
Chloride	74.2	55.9	17.1
Ammonia Nitrogen	< 0.2	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	0.32	0.58	1.1
Total Phosphorus	0.0217	0.0622	0.142
pH	7.53	7.25	7.20

Table 2. Analytical results – Wheel Creek automated sampling, Peak Limb			
Constituent	**6/7-Dec-16**		
	Station WC002 (mg/L)	**Station WC003 (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	< 2	2.4	< 2
Nitrate Nitrogen	0.224	0.311	0.459
Nitrate-Nitrite Nitrogen	0.224	0.311	0.459
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	20	7.2	21.5
Copper	0.0057	0.0067	0.006
Lead	0.00078	0.00084	0.00077
Zinc	0.0174	0.0167	0.0238
Chloride	10.6	16.3	6.99
Ammonia Nitrogen	< 0.2	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	0.573	0.536	0.534
Total Phosphorus	0.0789	1.24	0.0378
pH	7.54	7.33	7.28

Table 3. Analytical results – Wheel Creek automated sampling, Falling Limb			
Constituent	**6/7-Dec-16**		
	Station WC002 (mg/L)	**Station WC003 (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	< 2	2.4	< 2
Nitrate Nitrogen	0.38	0.314	0.335
Nitrate-Nitrite Nitrogen	0.38	0.314	0.335
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	4.4	< 5	< 4
Copper	0.0054	0.0052	0.005
Lead	0.00057	0.00059	0.00056
Zinc	0.0145	0.0155	0.0216
Chloride	21.9	22.8	12.1
Ammonia Nitrogen	< 0.2	< 0.2	< 0.2
Kjeldahl Nitrogen (Total)	0.483	0.536	0.325
Total Phosphorus	0.0376	0.0403	< 0.05
pH	7.23	7.12	7.19

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Table 4. Analytical Results – Wheel Creek Grab Sampling

Constituent	Station WC002	Station WC003	Station WC004
December 6, 2016 (Rising)			
TPH (mg/L)	< 5	< 5	< 5
E. coli (MPN/100 ml)	138	49.6	27.2
Temp (C)	7.8	8.6	8.9
DO (mg/L)	10.96	10.49	9.69
pH	7.30	7.20	6.89
Sp. Cond. (mS/cm)	0.386	0.404	0.679

Table 5. Rainfall and flow statistics

Constituent	Station WC002	Station WC003	Station WC004
Rainfall (in.)	0.79	0.79	0.79
Duration (hrs.)	36	40	36
Intensity (in./hr.)	0.0219	0.0197	0.0219
Discharge Volume (ft^3)	231,320	132,452	86,557

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WHEEL CREEK STORM MONITORING SUMMARY REPORT

FEBRUARY 28-MARCH 1, 2017

INTRODUCTION

On February 28-March 1, Versar conducted storm monitoring at the Wheel Creek stations. Samples were successfully collected at Station WC004 using the Sigma 900Max automated sampler. This report presents water chemistry results for this event.

Site locations were as follows:

- Station WC004: Located on north side of Wheel Court. Level logger is located downstream of storm shelter.
- Station WC003: Located on south side of Cinnabar Lane, west of Wheel Road. Storm event flow sensor was located within outfall pipe. *WC003 was offline due to construction.
- Station WC002: Located on south side of Wheel Road, just west of junction of Arthurs Woods Drive. Storm event flow sensor was located within culvert.

RESULTS

Versar field staff traveled to the sites on February 28 to deploy siphon samplers and program the Sigma automated samplers to sample the event. Rainfall began occurring just after 5:55 p.m. the evening of February 28. A rainfall total of 0.18 inches was recorded at the Wheel Creek Rain Gauge Station.

On the evening of February 28, field staff collected grab water samples to be tested for TPH and *E. coli* at two of the three stations (WC003 was offline) shortly after rainfall began, during the first flush. The *E. coli* samples were submitted to Enviro-Chem Laboratories for analysis shortly after collection.

Field staff traveled to the sites on March 1 to composite automated and suspended sediment samples (SSC). SSC siphon samples were submitted to the laboratory for analysis on March 2. Due to technical issues with the Sigma sampler at station WC002, only composite samples from WC004 and TPH samples (WC002 & WC004), were transported to the Harford County offices for pickup by Eurofins QC on March 1.

Hydrographs for the February 28-March 1 storm are presented in Figure 1 and Figure 2 below. Laboratory analytical and field water quality results for the February 28-March 1 storm are shown in Table 1 through Table 4. Rainfall and flow statistics for the event are shown in Table 5.

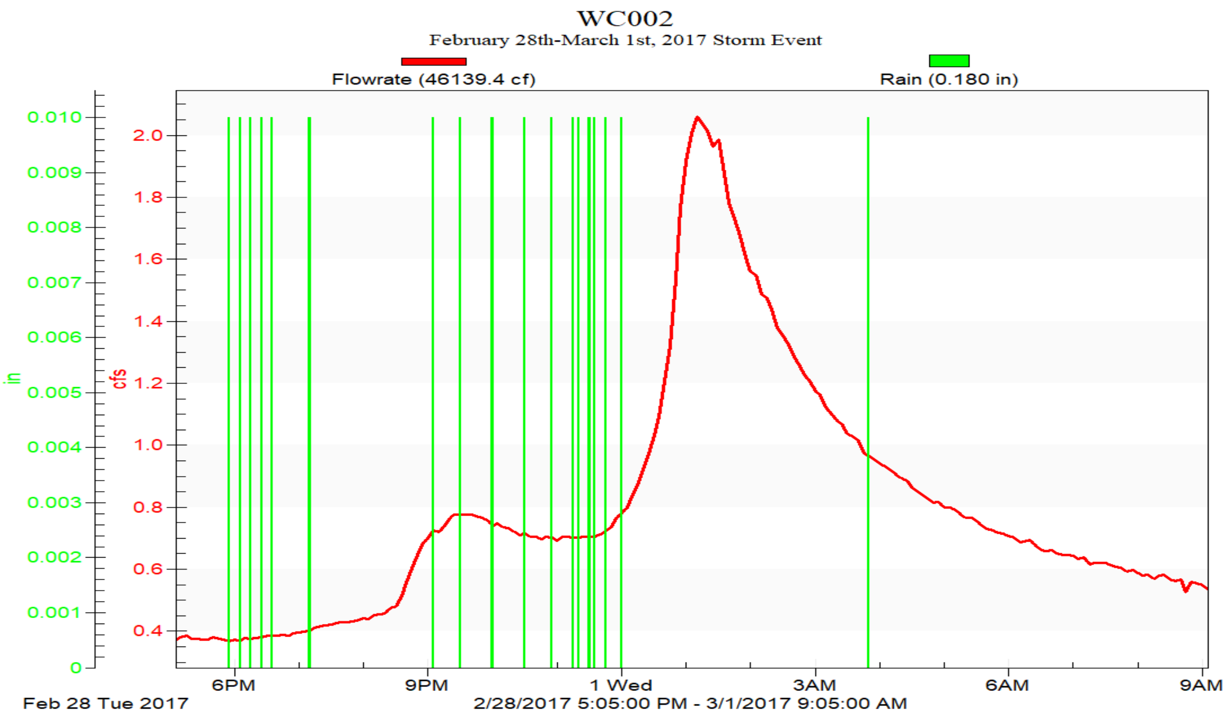

Figure 1. Hydrograph at Station WC002 for February 28-March 1, 2017 storm. Rainfall data source: Wheel Creek Rain Gauge Station

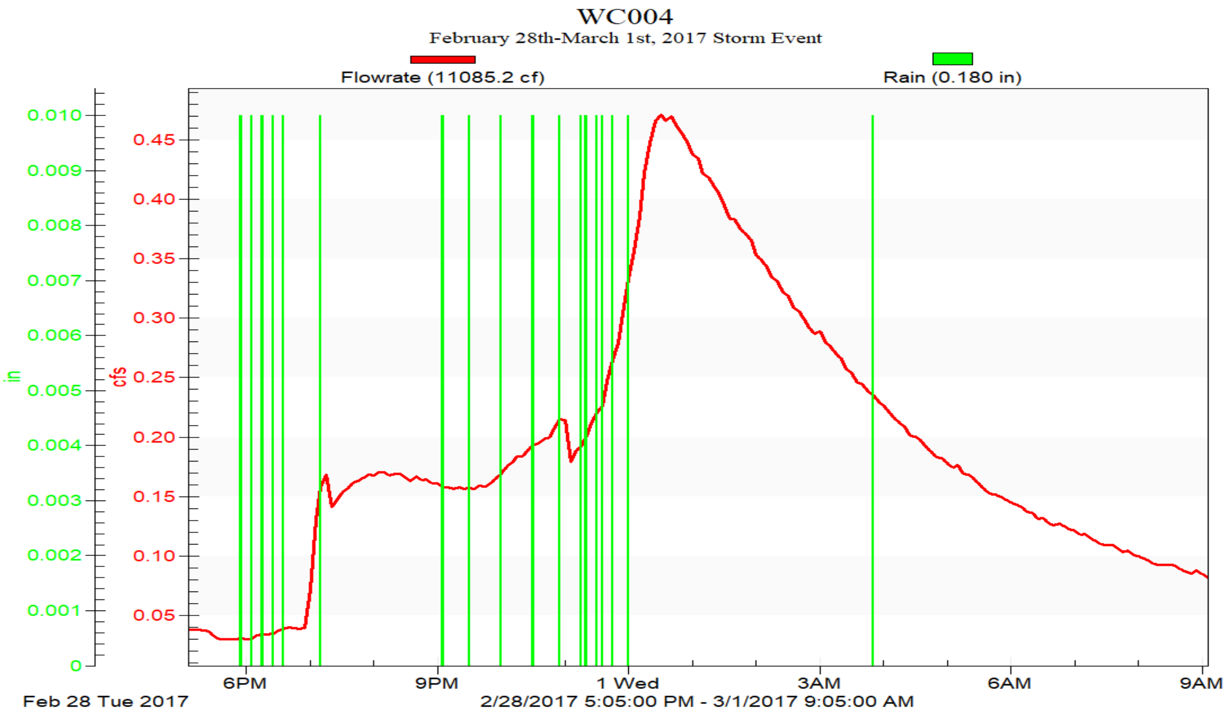

Figure 2. Hydrograph at Station WC004 for February 28-March 1, 2017 storm. Rainfall data source: Wheel Creek Rain Gauge Station

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Table 1. Analytical results – Wheel Creek automated sampling, Rising Limb			
Constituent	**1-Mar-17**		
	Station WC002 (mg/L)	**Station WC003* (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	N/C	N/C	5
Nitrate Nitrogen	N/C	N/C	2.47
Nitrate-Nitrite Nitrogen	N/C	N/C	2.47
Orthophosphate Phosphorus	N/C	N/C	< 0.05
Solids (Suspended)	N/C	N/C	4.4
Copper	N/C	N/C	0.0072
Lead	N/C	N/C	0.00051
Zinc	N/C	N/C	0.0328
Chloride	N/C	N/C	267
Ammonia Nitrogen	N/C	N/C	< 0.2
Kjeldahl Nitrogen (Total)	N/C	N/C	0.544
Total Phosphorus	N/C	N/C	0.0193
pH	N/C	N/C	7.76
*WC003 offline, "N/C": Not Collected			

Table 2. Analytical results – Wheel Creek automated sampling, Peak Limb			
Constituent	**1-Mar-17**		
	Station WC002 (mg/L)	**Station WC003* (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	N/C	N/C	3
Nitrate Nitrogen	N/C	N/C	0.545
Nitrate-Nitrite Nitrogen	N/C	N/C	0.715
Orthophosphate Phosphorus	N/C	N/C	< 0.05
Solids (Suspended)	N/C	N/C	5.6
Copper	N/C	N/C	0.011
Lead	N/C	N/C	0.00076
Zinc	N/C	N/C	0.0277
Chloride	N/C	N/C	90.1
Ammonia Nitrogen	N/C	N/C	< 0.2
Kjeldahl Nitrogen (Total)	N/C	N/C	0.773
Total Phosphorus	N/C	N/C	0.0455
pH	N/C	N/C	7.66
*WC003 offline, "N/C": Not Collected			

Table 3. Analytical results – Wheel Creek automated sampling, Falling Limb

Constituent	1-Mar-17 Station WC002 (mg/L)	Station WC003* (mg/L)	Station WC004 (mg/L)
5-Day BOD	N/C	N/C	< 2
Nitrate Nitrogen	N/C	N/C	0.667
Nitrate-Nitrite Nitrogen	N/C	N/C	0.838
Orthophosphate Phosphorus	N/C	N/C	< 0.05
Solids (Suspended)	N/C	N/C	< 4
Copper	N/C	N/C	0.0089
Lead	N/C	N/C	0.00063
Zinc	N/C	N/C	0.0244
Chloride	N/C	N/C	97.3
Ammonia Nitrogen	N/C	N/C	< 0.2
Kjeldahl Nitrogen (Total)	N/C	N/C	0.661
Total Phosphorus	N/C	N/C	0.033
pH	N/C	N/C	7.54

*WC003 offline, "N/C": Not Collected

Table 4. Analytical Results – Wheel Creek Grab Sampling

Constituent	Station WC002	Station WC003	Station WC004
February 28, 2017 (Rising)			
TPH (mg/L)	< 5	N/C	< 5
E. coli (MPN/100 ml)	98.5	N/C	111
Temp (C)	11.7	N/C	11.7
DO (mg/L)	9.89	N/C	8.47
pH	6.71	N/C	6.22
Sp. Cond. (mS/cm)	0.630	N/C	1.015

*WC003 offline, "N/C": Not Collected

Table 5. Rainfall and flow statistics

Constituent	Station WC002	Station WC003	Station WC004
Rainfall (in.)	0.18	0.18	0.18
Duration (hrs.)	21	N/A	21
Intensity (in./hr.)	0.0086	N/A	0.0086
Discharge Volume (ft^3)	54,663	N/A	12,312

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WHEEL CREEK STORM MONITORING SUMMARY REPORT

MARCH 18, 2017

INTRODUCTION

On March 18, Versar conducted snow melt monitoring at the Wheel Creek stations. Samples were successfully collected at Stations WC002 and WC004 using the Sigma 900Max automated samplers. This report presents water chemistry results for this event.

Site locations were as follows:

- Station WC004: Located on north side of Wheel Court. Level logger is located downstream of storm shelter.
- Station WC003: Located on south side of Cinnabar Lane, west of Wheel Road. Storm event flow sensor was located within outfall pipe. *WC003 was offline due to construction.
- Station WC002: Located on south side of Wheel Road, just west of junction of Arthurs Woods Drive. Storm event flow sensor was located within culvert.

RESULTS

Versar field staff traveled to the site on March 18 to deploy siphon samplers and program the Sigma automated samplers to sample the event. Snow melt initiated at approximately 9:00 a.m. the morning of March 18. The Bel Air South area accumulated about 3.0 inches of snow cover on March 14 to March 15 according to the National Weather Service.

Since the event occurred on a weekend (Saturday) and the event was not planned, the lab was unavailable to accept *E. coli* samples and TPH was not sampled.

Field staff traveled to the sites on March 20 to composite automated and suspended sediment samples (SSC). SSC siphon, composite and TPH samples were transported to the Harford County government offices to await pickup by Eurofins QC and Enviro-Chem Laboratories on March 20.

Hydrographs for the March 18 snow melt are presented in Figure 1 and Figure 2 below. Laboratory analytical and field water quality results for the March 18 snow melt are shown in Table 1 through Table 3. Precipitation and flow statistics for the event are shown in Table 4.

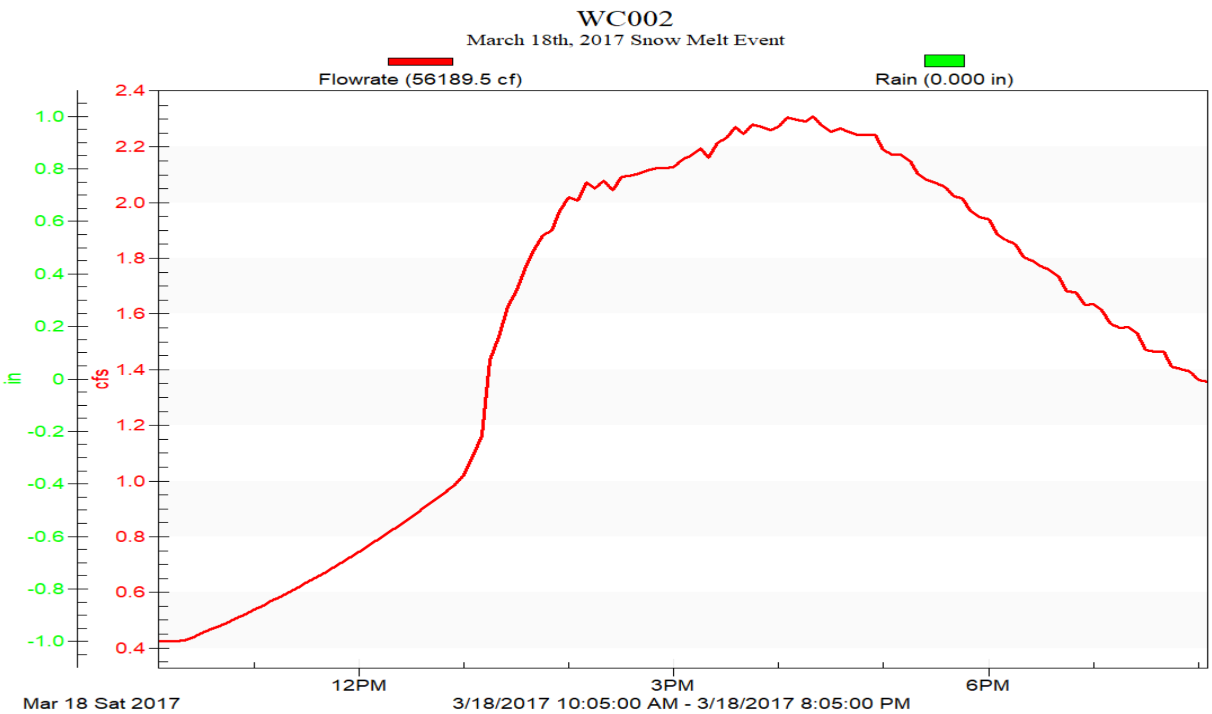

Figure 1. Hydrograph at Station WC002 for March 18, 2017 snow melt (no rainfall data)

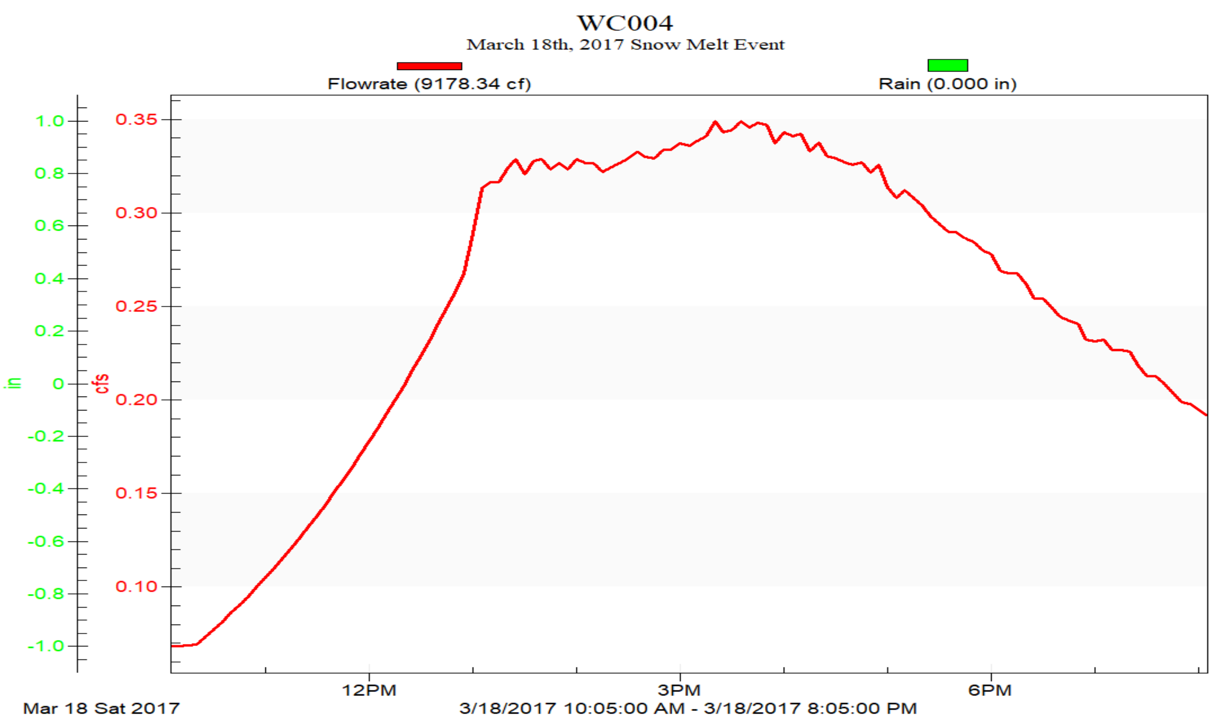

Figure 2. Hydrograph at Station WC004 for March 18, 2017 snow melt (no rainfall data)

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Table 1. Analytical results – Wheel Creek automated sampling, Rising Limb			
Constituent	**18-Mar-17**		
	Station WC002 (mg/L)	**Station WC003* (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	6	N/C	< 2
Nitrate Nitrogen	0.895	N/C	0.512
Nitrate-Nitrite Nitrogen	0.895	N/C	0.512
Orthophosphate Phosphorus	< 0.05	N/C	< 0.05
Solids (Suspended)	4	N/C	89.6
Copper	0.0051	N/C	0.0092
Lead	0.00025	N/C	0.0034
Zinc	0.0213	N/C	0.0314
Chloride	439	N/C	424
Ammonia Nitrogen	< 0.2	N/C	< 0.2
Kjeldahl Nitrogen (Total)	0.285	N/C	0.722
Total Phosphorus	< 0.05	N/C	0.0761
pH	7.35	N/C	7.55
Conductivity (mS/cm)	0.762	N/C	1.127
*WC003 offline, “N/C”: Not Collected			

Table 2. Analytical results – Wheel Creek automated sampling, Peak Limb			
Constituent	**18-Mar-17**		
	Station WC002 (mg/L)	**Station WC003* (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	4	N/C	< 2
Nitrate Nitrogen	0.567	N/C	0.447
Nitrate-Nitrite Nitrogen	0.567	N/C	0.447
Orthophosphate Phosphorus	< 0.05	N/C	< 0.05
Solids (Suspended)	4.4	N/C	< 4
Copper	0.0046	N/C	0.0069
Lead	0.00038	N/C	0.00078
Zinc	0.0187	N/C	0.023
Chloride	403	N/C	390
Ammonia Nitrogen	< 0.2	N/C	< 0.2
Kjeldahl Nitrogen (Total)	0.426	N/C	0.403
Total Phosphorus	0.0328	N/C	0.0189
pH	7.45	N/C	7.52
Conductivity (mS/cm)	0.813	N/C	1.079
*WC003 offline, “N/C”: Not Collected			

Table 3. Analytical results – Wheel Creek automated sampling, Falling Limb

Constituent	18-Mar-17 Station WC002 (mg/L)	Station WC003* (mg/L)	Station WC004 (mg/L)
5-Day BOD	5	N/C	< 2
Nitrate Nitrogen	0.598	N/C	0.532
Nitrate-Nitrite Nitrogen	0.598	N/C	0.532
Orthophosphate Phosphorus	< 0.05	N/C	< 0.05
Solids (Suspended)	4	N/C	< 4
Copper	0.0068	N/C	0.0057
Lead	0.00036	N/C	0.00075
Zinc	0.022	N/C	0.0267
Chloride	333	N/C	369
Ammonia Nitrogen	< 0.2	N/C	< 0.2
Kjeldahl Nitrogen (Total)	0.454	N/C	0.506
Total Phosphorus	0.0332	N/C	0.0279
pH	7.51	N/C	7.52
Conductivity (mS/cm)	0.977	N/C	1.050
*WC003 offline, "N/C": Not Collected			

Table 4. Rainfall and flow statistics

Constituent	Station WC002	Station WC003	Station WC004
Rainfall (in.)	N/A	N/A	N/A
Duration (hrs.)	N/A	N/A	N/A
Intensity (in./hr.)	N/A	N/A	N/A
Discharge Volume (ft^3)	56,189	N/A	9,178

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WHEEL CREEK STORM MONITORING SUMMARY REPORT

MARCH 31, 2017

INTRODUCTION

On March 31, Versar conducted storm monitoring at the Wheel Creek stations. Samples were successfully collected at Stations WC002 and WC004 using the Sigma 900Max automated samplers. This report presents water chemistry results for this event.

Site locations were as follows:

- Station WC004: Located on north side of Wheel Court. Level logger is located downstream of storm shelter.
- Station WC003: Located on south side of Cinnabar Lane, west of Wheel Road. Storm event flow sensor was located within outfall pipe. *WC003 was offline due to construction.
- Station WC002: Located on south side of Wheel Road, just west of junction of Arthurs Woods Drive. Storm event flow sensor was located within culvert.

RESULTS

Versar field staff traveled to the site on March 30 to deploy siphon samplers and program the Sigma automated samplers to sample the event. Rainfall initiated at approximately 4:20 a.m. the morning of March 31. A rainfall total of 1.49 inches was recorded at the Wheel Creek Rain Gauge Station.

On the morning of March 31, field staff collected grab water samples to be tested for TPH and *E. coli* at two of the three sites (WC003 was offline) around the peak limb of the storm event. First flush occurred between 12 a.m. and 6 a.m. The *E. coli* samples were submitted to Enviro-Chem Laboratories for analysis after collection.

Field staff traveled to the sites on April 2 to composite automated and suspended sediment samples (SSC). SSC siphon samples were submitted to the laboratory for analysis on April 4. Composite and TPH samples were picked up by Eurofins QC on April 2.

Hydrographs for the March 31 storm are presented in Figure 1 and Figure 2 below. Laboratory analytical and field water quality results for the March 31 storm are shown in Table 1 through Table 4. Rainfall and flow statistics for the event are shown in Table 5.

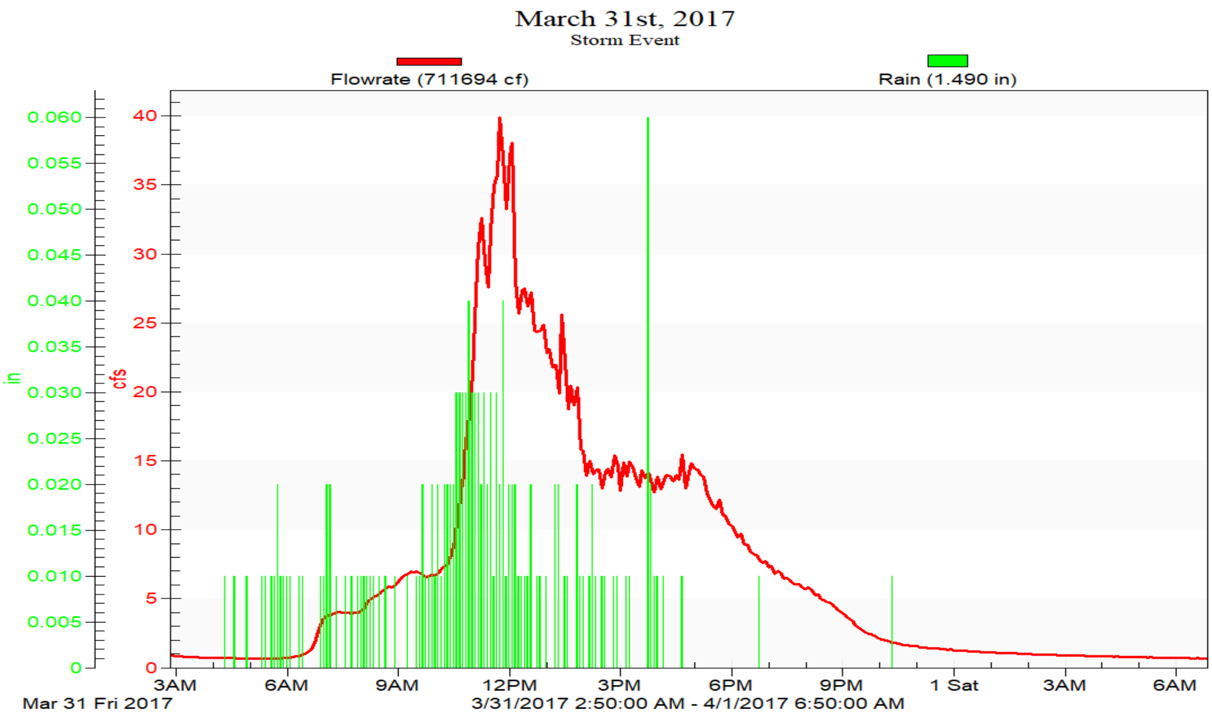

Figure 1. Hydrograph at Station WC002 for March 31, 2017 storm. Rainfall data source: Wheel Creek Rain Gauge Station

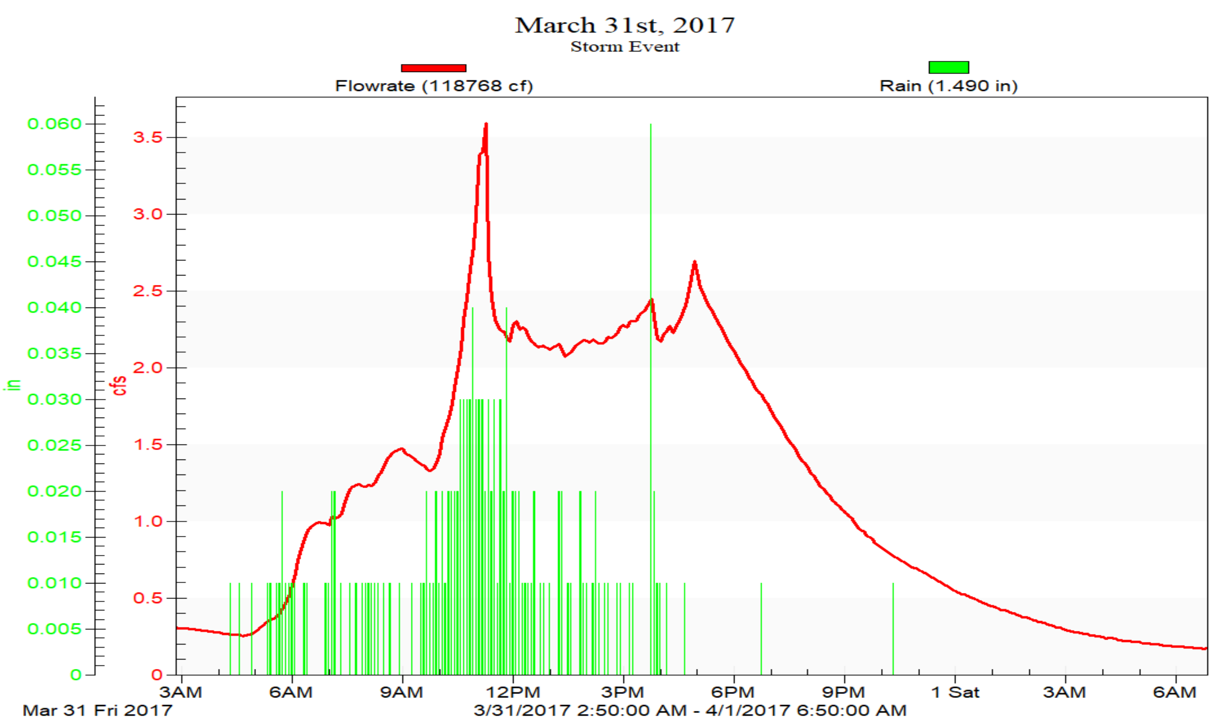

Figure 2. Hydrograph at Station WC004 for March 31, 2017 storm. Rainfall data source: Wheel Creek Rain Gauge Station

Table 1. Analytical results – Wheel Creek automated sampling, Rising Limb

Constituent	31-Mar-17		
	Station WC002 (mg/L)	Station WC003* (mg/L)	Station WC004 (mg/L)
5-Day BOD	< 2	N/C	3
Nitrate Nitrogen	0.83	N/C	0.397
Nitrate-Nitrite Nitrogen	0.83	N/C	0.397
Orthophosphate Phosphorus	< 0.05	N/C	< 0.05
Solids (Suspended)	19.2	N/C	43.2
Copper	0.0082	N/C	0.0125
Lead	0.00073	N/C	0.0017
Zinc	0.0239	N/C	0.0465
Chloride	151	N/C	215
Ammonia Nitrogen	0.178	N/C	< 0.2
Kjeldahl Nitrogen (Total)	0.735	N/C	0.985
Total Phosphorus	0.0458	N/C	0.0748
pH	7.71	N/C	7.50

*WC003 offline, "N/C": Not Collected

Table 2. Analytical results – Wheel Creek automated sampling, Peak Limb

Constituent	31-Mar-17		
	Station WC002 (mg/L)	Station WC003* (mg/L)	Station WC004 (mg/L)
5-Day BOD	6	N/C	5
Nitrate Nitrogen	0.348	N/C	0.225
Nitrate-Nitrite Nitrogen	0.348	N/C	0.225
Orthophosphate Phosphorus	< 0.05	N/C	< 0.05
Solids (Suspended)	106	N/C	45.4
Copper	0.0101	N/C	0.0102
Lead	0.0022	N/C	0.0014
Zinc	0.0356	N/C	0.0342
Chloride	51.4	N/C	96.4
Ammonia Nitrogen	< 0.2	N/C	< 0.2
Kjeldahl Nitrogen (Total)	1.1	N/C	0.563
Total Phosphorus	0.185	N/C	0.0683
pH	7.68	N/C	7.55

*WC003 offline, "N/C": Not Collected

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Table 3. Analytical results – Wheel Creek automated sampling, Falling Limb

Constituent	31-Mar-17 Station WC002 (mg/L)	Station WC003* (mg/L)	Station WC004 (mg/L)
5-Day BOD	5	N/C	2
Nitrate Nitrogen	0.835	N/C	0.343
Nitrate-Nitrite Nitrogen	0.835	N/C	0.343
Orthophosphate Phosphorus	< 0.05	N/C	< 0.05
Solids (Suspended)	7.2	N/C	9.2
Copper	0.0073	N/C	0.0059
Lead	0.00063	N/C	0.00073
Zinc	0.0187	N/C	0.0438
Chloride	84.3	N/C	118
Ammonia Nitrogen	< 0.2	N/C	< 0.2
Kjeldahl Nitrogen (Total)	0.668	N/C	0.469
Total Phosphorus	0.0478	N/C	0.0283
pH	7.30	N/C	7.35
*WC003 offline, “N/C”: Not Collected			

Table 4. Analytical Results – Wheel Creek Grab Sampling

Constituent	Station WC002	Station WC003*	Station WC004
March 31, 2017 (Peak)			
TPH (mg/L)	< 5	N/C	< 5
E. coli (MPN/100 ml)	> 2420	N/C	214
Temp (C)	7.2	N/C	7.6
DO (mg/L)	11.38	N/C	11.26
pH	8.10	N/C	7.84
Sp. Cond. (mS/cm)	0.217	N/C	0.382
*WC003 offline, “N/C”: Not Collected			

Table 5. Rainfall and flow statistics

Constituent	Station WC002	Station WC003	Station WC004
Rainfall (in.)	1.49	1.49	1.49
Duration (hrs.)	26	N/A	26
Intensity (in./hr.)	0.0573	N/A	0.0573
Discharge Volume (ft^3)	706,345	N/A	118,104

WHEEL CREEK STORM MONITORING SUMMARY REPORT

MAY 4-5, 2017

INTRODUCTION

On May 4-5, Versar conducted storm monitoring at the Wheel Creek stations. Samples were successfully collected at Stations WC002, WC003, and WC004 using the Sigma 900Max automated samplers. This report presents water chemistry results for this event.

Site locations are as follows:

- Station WC004: Located on north side of Wheel Court. Level logger is located downstream of storm shelter.
- Station WC003: Located on south side of Cinnabar Lane, west of Wheel Road. Flow sensor is located within outfall pipe.
- Station WC002: Located on south side of Wheel Road, just west of junction of Arthurs Woods Drive. Flow sensor is located within culvert.

RESULTS

Versar field staff traveled to the sites on May 4 to deploy siphon samplers and program the Sigma automated samplers to sample the event. Rainfall initiated at approximately 10:40 p.m. the night of May 4. A rainfall total of 1.31 inches was recorded at the Wheel Creek Rain Gauge Station.

On the morning of May 5, field staff collected grab water samples to be tested for TPH and *E. coli* at each station shortly after first flush began during the rising limb of the storm event. The *E. coli* samples were submitted to Enviro-Chem Laboratories for analysis after collection.

Field staff traveled to the sites on May 7 to composite automated and suspended sediment samples (SSC). SSC siphon samples were submitted to the laboratory for analysis on May 8. Composite and TPH samples were transported to the Harford County government offices to await pickup by Eurofins QC on May 7.

Hydrographs for the May 4-5 storm are presented in Figure 1 through Figure 3 below. Laboratory analytical and field water quality results for the May 4-5 storm are shown in Table 1 through Table 4. Rainfall and flow statistics for the event are shown in Table 5.

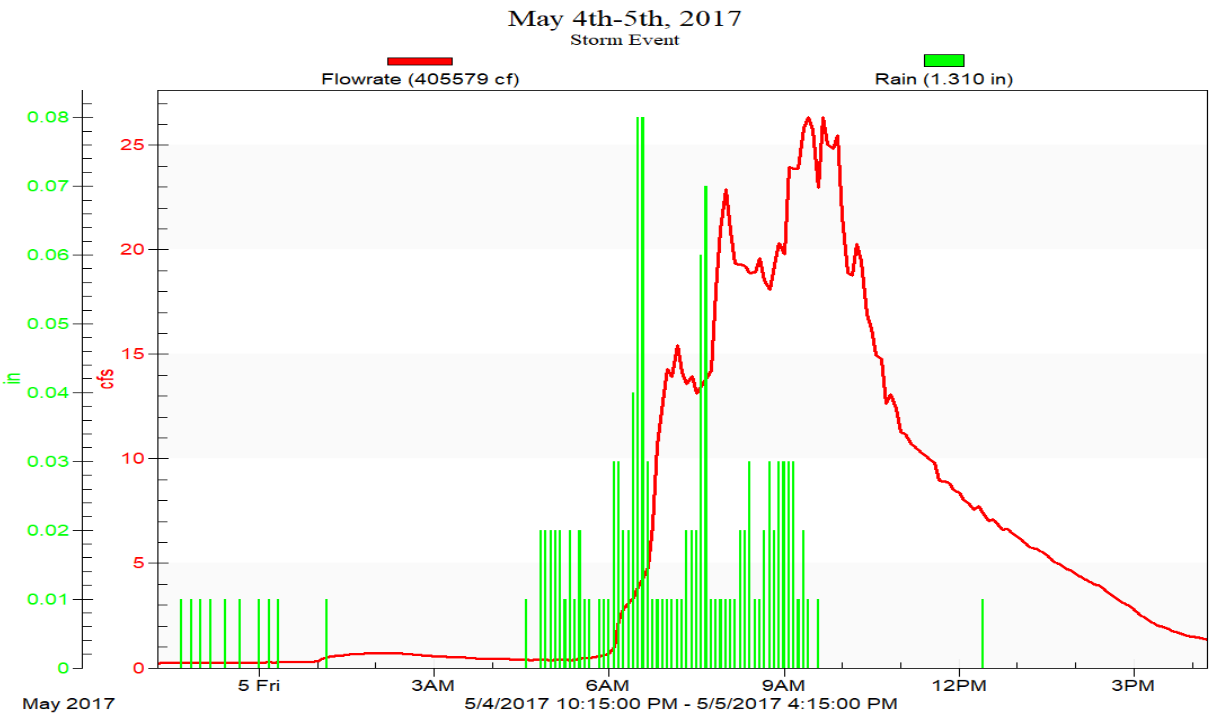

Figure 1. Hydrograph at Station WC002 for May 4-5, 2017 storm. Rainfall data source: Wheel Creek Rain Gauge Station

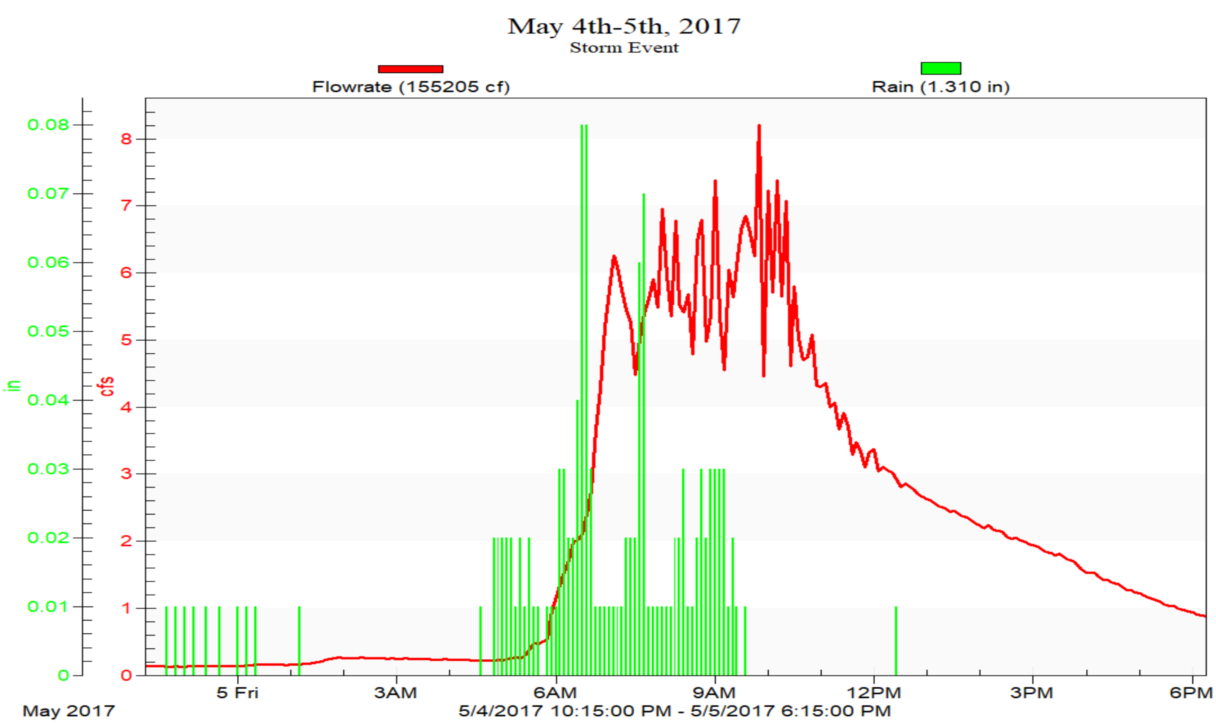

Figure 2. Hydrograph at Station WC003 for May 4-5, 2017 storm. Rainfall data source: Wheel Creek Rain Gauge Station

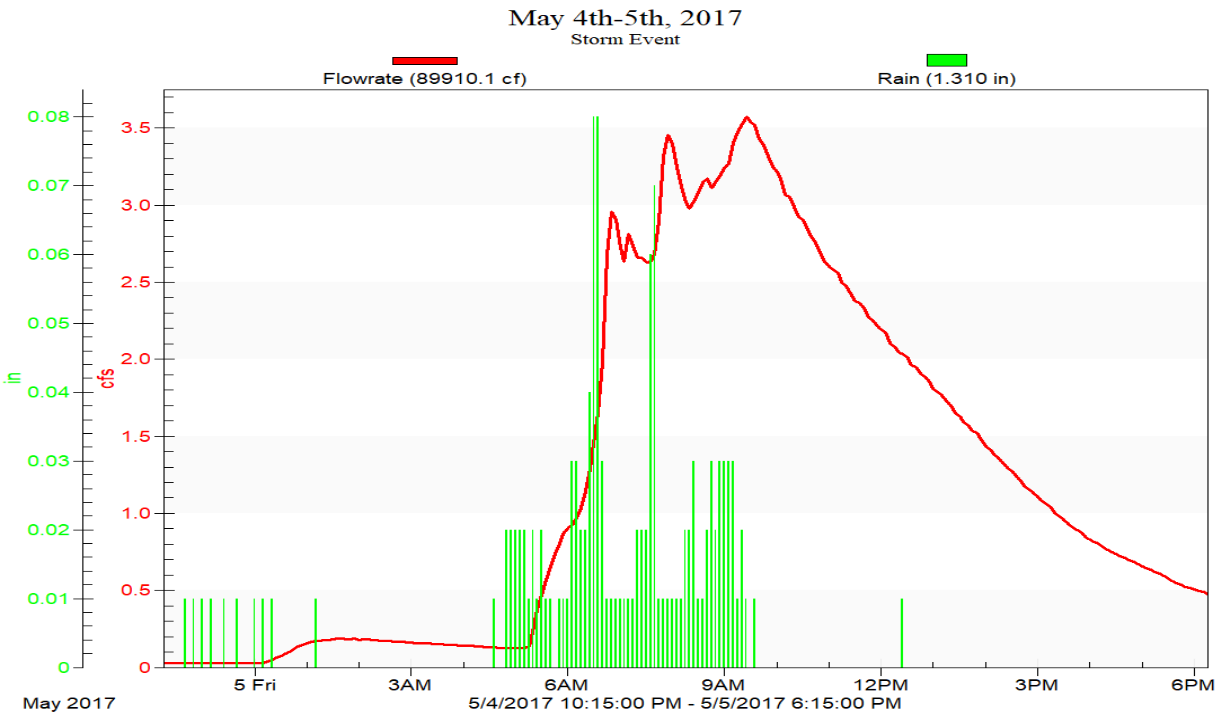

Figure 3. Hydrograph at Station WC004 for May 4-5, 2017 storm. Rainfall data source: Wheel Creek Rain Gauge Station

Table 1. Analytical results – Wheel Creek automated sampling, Rising Limb

Constituent	4/5-May-17		
	Station WC002 (mg/L)	Station WC003 (mg/L)	Station WC004 (mg/L)
5-Day BOD	17	15	15
Nitrate Nitrogen	1.08	0.742	0.635
Nitrate-Nitrite Nitrogen	1.29	0.944	0.786
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	125	184	107
Copper	0.0124	0.0184	0.0171
Lead	0.003	0.0062	0.0038
Chloride	82.1	91.9	35.3
Zinc	0.0665	0.0996	0.0755
Ammonia Nitrogen	< 0.2	< 0.2	0.354
Kjeldahl Nitrogen (Total)	1.61	1.89	1.86
Total Phosphorus	0.258	0.315	0.242
pH	7.52	7.1	7.35

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Table 2. Analytical results – Wheel Creek automated sampling, Peak Limb			
Constituent	**4/5-May-17**		
	Station WC002 (mg/L)	**Station WC003 (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	11	19	12
Nitrate Nitrogen	0.422	0.269	0.428
Nitrate-Nitrite Nitrogen	0.531	0.391	0.533
Orthophosphate Phosphorus	<0.05	<0.05	<0.05
Solids (Suspended)	55.6	45.6	98
Copper	0.0102	0.0116	0.0161
Lead	0.0011	0.0016	0.0035
Zinc	0.0249	0.0296	0.0592
Chloride	20.1	32.9	15.3
Ammonia Nitrogen	<0.2	0.15	0.145
Kjeldahl Nitrogen (Total)	0.869	0.967	1.26
Total Phosphorus	0.102	0.119	0.173
pH	7.78	7.30	7.37

Table 3. Analytical results – Wheel Creek automated sampling, Falling Limb			
Constituent	**4/5-May-17**		
	Station WC002 (mg/L)	**Station WC003 (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	10	11	13
Nitrate Nitrogen	0.465	0.292	0.459
Nitrate-Nitrite Nitrogen	0.589	0.418	0.586
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	17.6	12.8	30
Copper	0.0095	0.0069	0.01
Lead	0.00077	0.00061	0.0015
Zinc	0.0206	0.0139	0.0312
Chloride	24.7	38.6	25.3
Ammonia Nitrogen	< 0.2	0.226	0.335
Kjeldahl Nitrogen (Total)	0.781	0.649	0.861
Total Phosphorus	0.0862	0.0447	0.0705
pH	7.36	7.15	7.07

Table 4. Analytical Results – Wheel Creek Grab Sampling			
Constituent	**Station WC002**	**Station WC003**	**Station WC004**
May 5, 2017 (Rising)			
TPH (mg/L)	< 5	< 5	< 5
E. coli (MPN/100 ml)	> 2420	> 2420	> 2420
Temp (C)	12.2	12.1	14.3
DO (mg/L)	9.22	9.14	7.43
pH	6.82	6.98	7.16
Sp. Cond. (mS/cm)	0.608	0.616	0.295

Table 5. Rainfall and flow statistics			
Constituent	**Station WC002**	**Station WC003**	**Station WC004**
Rainfall (in.)	1.31	1.31	1.31
Duration (hrs.)	42	42	42
Intensity (in./hr.)	0.0312	0.0312	0.0312
Discharge Volume (ft^3)	461,504	191,706	107,214

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VERSAR

WHEEL CREEK STORM MONITORING SUMMARY REPORT

JUNE 19-20, 2017

INTRODUCTION

On June 19-20, Versar conducted storm monitoring at the Wheel Creek stations. Samples were successfully collected at Stations WC002, WC003, and WC004 using the Sigma 900Max automated samplers. This report presents water chemistry results for this event.

Site locations are as follows:

- Station WC004: Located on north side of Wheel Court. Level logger is located downstream of storm shelter.
- Station WC003: Located on south side of Cinnabar Lane, west of Wheel Road. Flow sensor is located within outfall pipe.
- Station WC002: Located on south side of Wheel Road, just west of junction of Arthurs Woods Drive. Flow sensor is located within culvert.

RESULTS

Versar field staff traveled to the sites on June 19 to deploy siphon samplers and program the Sigma automated samplers to sample the event. Rainfall initiated at approximately 3:35 p.m. the afternoon of June 19. A rainfall total of 0.95 inches was recorded at the Wheel Creek Rain Gauge Station.

No *E. coli* samples or water quality data were taken due to severe weather. TPH was taken at the time of compositing but the stream had returned to baseflow.

Field staff traveled to the sites on June 20 to composite automated and suspended sediment samples (SSC). SSC siphon samples were submitted to the laboratory for analysis on June 21. Composite and TPH samples were transported to the Harford County Government offices to await pickup by Eurofins QC on June 20.

Hydrographs for the June 19-20 storm are presented in Figure 1 through Figure 3 below. Laboratory analytical and field water quality results for the June 19-20 storm are shown in Table 1 through Table 4. Rainfall and flow statistics for the event are shown in Table 5.

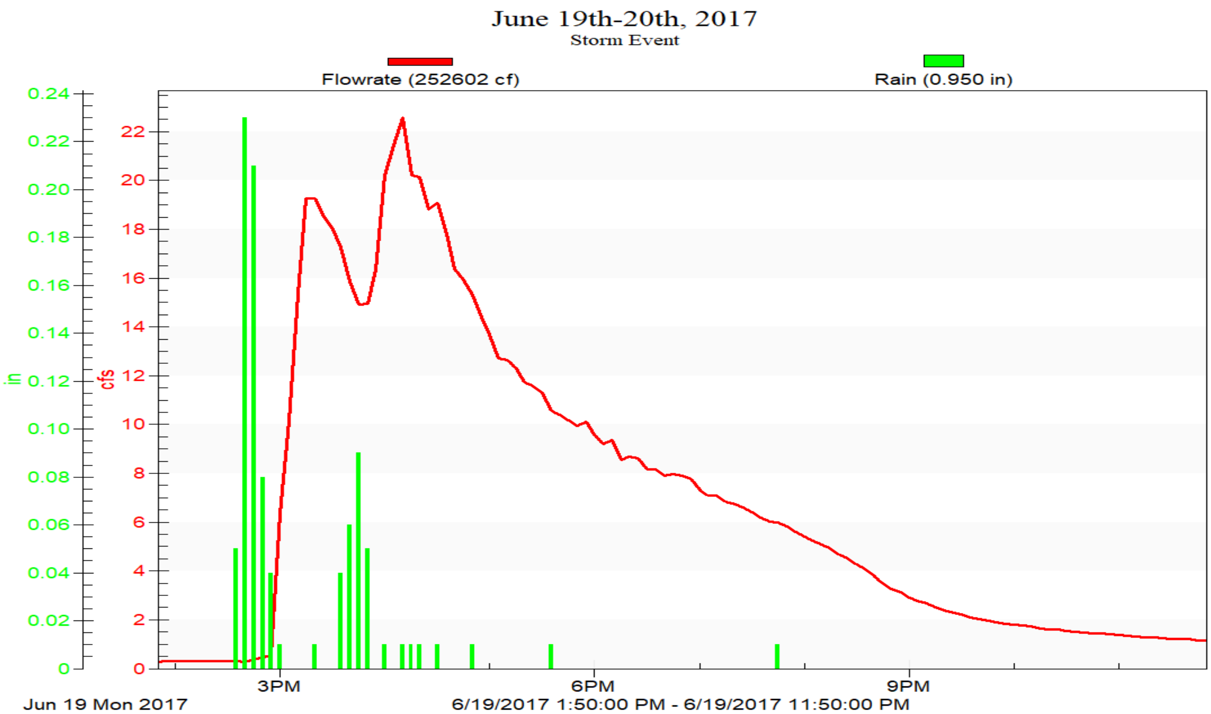

Figure 1. Hydrograph at Station WC002 for June 19-20, 2017 storm. Rainfall data source: Wheel Creek Rain Gauge Station

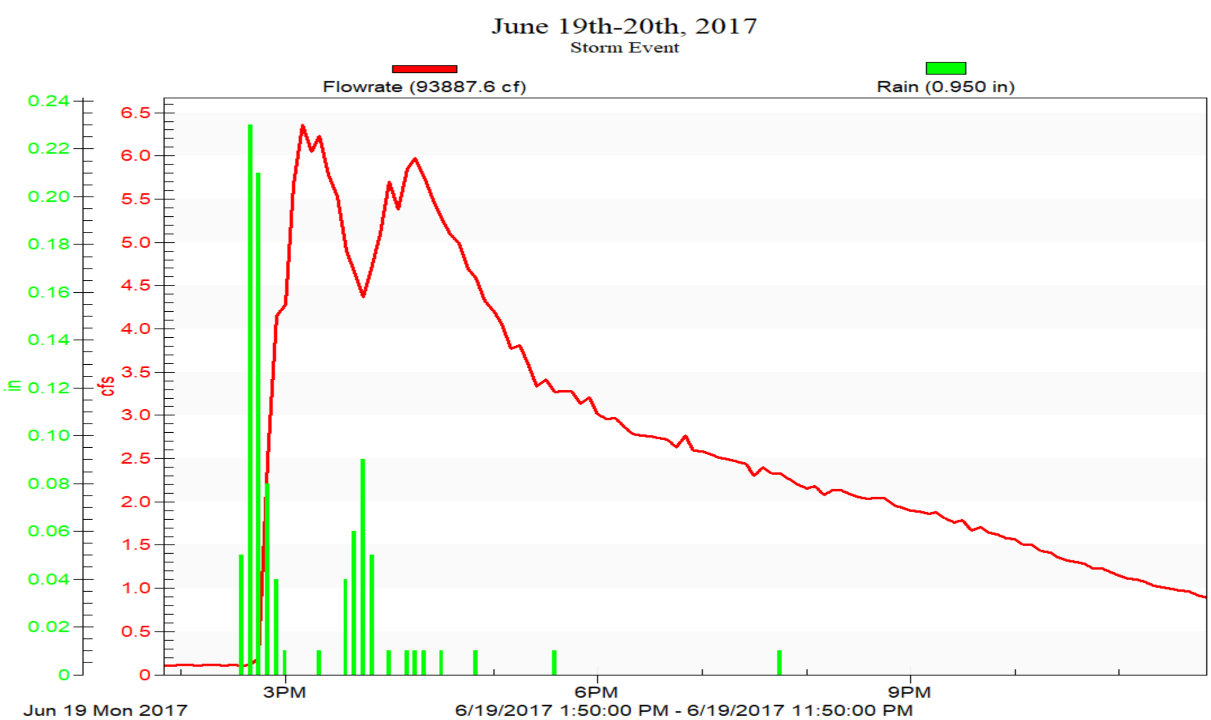

Figure 2. Hydrograph at Station WC003 for June 19-20, 2017 storm. Rainfall data source: Wheel Creek Rain Gauge Station

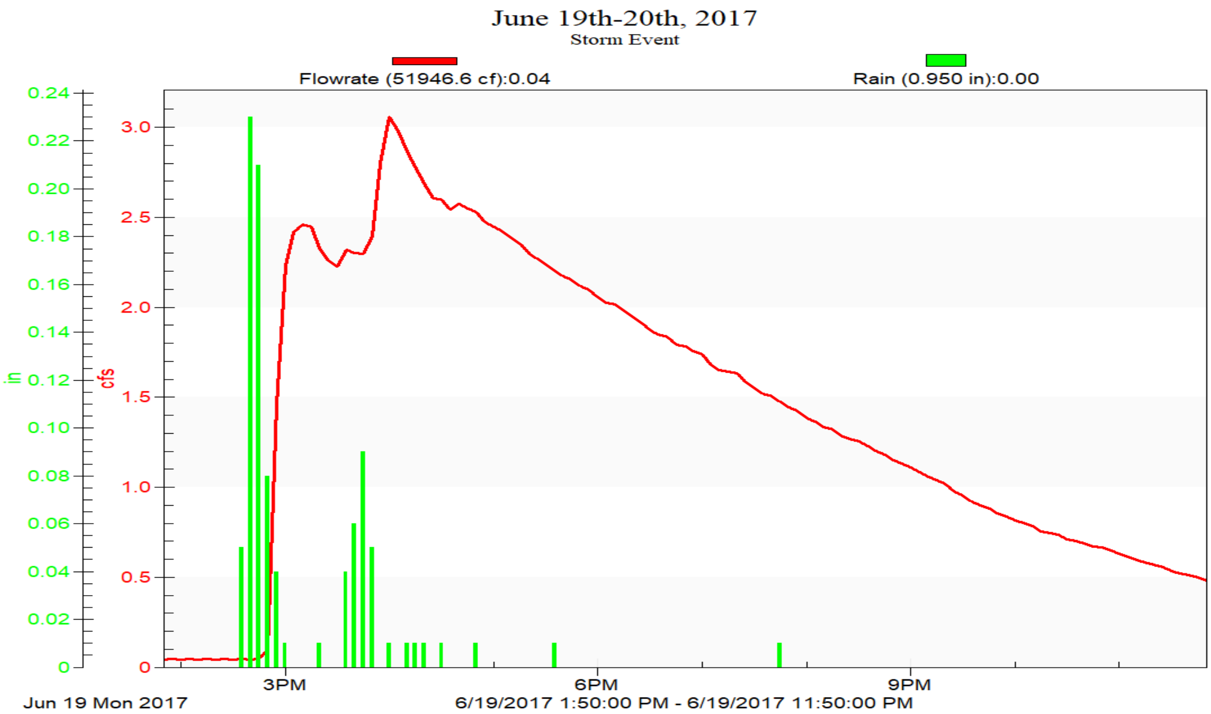

Figure 3. Hydrograph at Station WC004 for June 19-20, 2017 storm. Rainfall data source: Wheel Creek Rain Gauge Station

Table 1. Analytical results – Wheel Creek automated sampling, Rising Limb

Constituent	19/20-Jun-17 Station WC002 (mg/L)	Station WC003 (mg/L)	Station WC004 (mg/L)
5-Day BOD	22	19	12
Nitrate Nitrogen	0.621	0.505	0.351
Nitrate-Nitrite Nitrogen	0.712	0.597	0.417
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	229	219	142
Copper	0.0226	0.0343	0.0409
Lead	0.0077	0.0089	0.0143
Zinc	0.114	0.127	0.141
Chloride	41	49.9	20.6
Ammonia Nitrogen	0.0694	0.121	< 0.2
Kjeldahl Nitrogen (Total)	2.76	2.05	2.16
Total Phosphorus	0.492	0.357	0.428
pH	7.32	7.30	7.29

Table 2. Analytical results – Wheel Creek automated sampling, Peak Limb			
Constituent	**19/20-Jun-17**		
	Station WC002 (mg/L)	**Station WC003 (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	16	15	11
Nitrate Nitrogen	0.45	0.413	0.374
Nitrate-Nitrite Nitrogen	0.526	0.497	0.442
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	50	40.4	65.6
Copper	0.0105	0.0124	0.0195
Lead	0.0017	0.0019	0.0038
Zinc	0.0316	0.0355	0.0643
Chloride	21.1	34.4	19.6
Ammonia Nitrogen	< 0.2	0.0808	0.131
Kjeldahl Nitrogen (Total)	1.14	1.26	1.23
Total Phosphorus	0.175	0.165	0.176
pH	7.38	7.25	7.26

Table 3. Analytical results – Wheel Creek automated sampling, Falling Limb			
Constituent	**19/20-Jun-17**		
	Station WC002 (mg/L)	**Station WC003 (mg/L)**	**Station WC004 (mg/L)**
5-Day BOD	9	13	8
Nitrate Nitrogen	0.447	0.334	0.272
Nitrate-Nitrite Nitrogen	0.527	0.409	0.334
Orthophosphate Phosphorus	< 0.05	< 0.05	< 0.05
Solids (Suspended)	18	7.2	16.4
Copper	0.0067	0.0046	0.0088
Lead	0.00075	0.00044	0.0012
Zinc	0.0194	0.0137	0.0298
Chloride	24.8	37.2	18.6
Ammonia Nitrogen	0.0709	< 0.2	0.0688
Kjeldahl Nitrogen (Total)	0.924	0.677	0.901
Total Phosphorus	0.104	0.043	0.0741
pH	7.30	7.28	7.19

Table 4. Analytical Results – Wheel Creek Grab Sampling			
Constituent	**Station WC002**	**Station WC003**	**Station WC004**
June 20, 2017 (Falling)			
TPH (mg/L)	< 5	< 5	< 5
E. coli (MPN/100 ml)	N/C	N/C	N/C
Temp (C)	N/C	N/C	N/C
DO (mg/L)	N/C	N/C	N/C
pH	N/C	N/C	N/C
Sp. Cond. (mS/cm)	N/C	N/C	N/C
"N/C": Not Collected			

Table 5. Rainfall and flow statistics			
Constituent	**Station WC002**	**Station WC003**	**Station WC004**
Rainfall (in.)	0.95	0.95	0.95
Duration (hrs.)	28	30	20
Intensity (in./hr.)	0.0339	0.0317	0.0475
Discharge Volume (ft^3)	286,995	113,346	58,060

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APPENDIX B

RATING CURVES

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Table B-1. Station WC002 rating curve from data points collected in 2016

Level (ft)	Flow Rate (cfs)
0.64	0.21
0.66	0.40
0.67	0.31
0.7	0.50
0.775	1.13
0.81	1.84
0.9	1.95
1.02	4.97
1.15	5.78
1.27	9.86
1.41	13.92
1.48	30.17

Table B-2. Station WC003 rating curve from data points collected in 2016

Level (ft)	Flow Rate (cfs)
0.58	0.07
0.63	0.11
0.73	0.35
0.835	0.77
0.93	0.88
0.985	1.79
1.02	2.13
1.175	4.02
1.26	6.05
1.285	6.96
1.35	9.25

Table B-3. Station WC004 rating curve from data points collected in 2016

Level (ft)	Flow Rate (cfs)
0.43	0.00
0.52	0.29
0.53	0.31
0.64	0.46
0.7	0.53
0.725	0.60
0.77	0.82
0.8	1.02
0.9	1.79
0.96	2.29
1.03	3.42
1.07	3.81

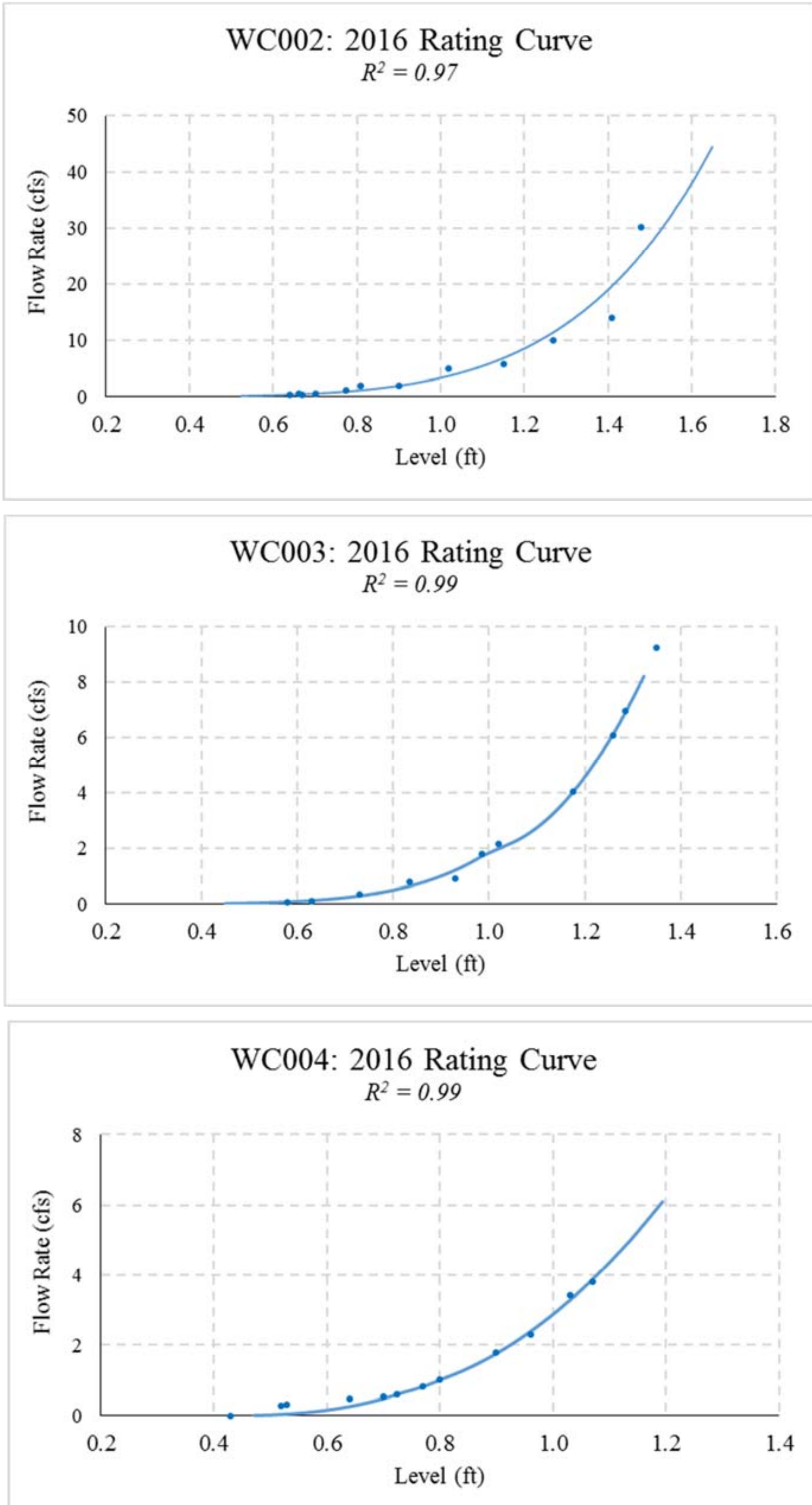

Figure B-1. Rating Curves for Stations WC002, WC003, and WC004

APPENDIX C

RAINFALL TOTALS

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Table C-1. July 2016-June 2017 rainfall data from USGS Atkisson (inches)												
Day	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**
1	0.00	0.27	0.18	0.22	0.00	0.02	0.00	0.00	0.08	0.00	0.04	0.00
2	0.00	0.05	0.00	0.01	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.04	0.02	0.00	0.72	0.00	0.00	0.22	0.00	0.00
4	0.68	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.01	0.07	0.00
5	0.21	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	1.30	0.10
6	0.00	0.05	0.00	0.00	0.00	0.78	0.00	0.00	0.00	1.05	0.04	0.44
7	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.05	0.01	0.01	0.01
8	1.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.01	0.00	0.00	0.02	0.18	0.00	0.00	0.34	0.00	0.00	0.00	0.01
10	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.23	0.00	0.00	0.00
11	0.00	0.00	0.00	0.01	0.00	0.00	0.31	0.00	0.00	0.00	0.32	0.00
12	0.00	0.00	0.00	0.00	0.00	0.24	0.03	0.32	0.00	0.00	0.11	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.00
14	0.00	0.34	0.00	0.00	0.00	0.00	0.12	0.00	0.44	0.00	0.01	0.00
15	0.00	0.34	0.01	0.00	0.00	0.00	0.10	0.00	0.08	0.02	0.00	0.00
16	0.09	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00
17	0.01	0.40	0.00	0.00	0.00	0.87	0.18	0.00	0.00	0.13	0.00	0.00
18	0.02	0.18	---	0.00	0.00	0.10	0.01	0.00	0.11	0.00	0.00	0.00
19	0.16	0.00	---	0.00	0.10	0.00	0.00	0.00	0.14	0.00	0.05	0.95
20	0.00	0.00	---	0.00	0.00	0.00	0.08	0.00	0.00	0.69	0.00	0.11
21	0.00	1.40	---	0.00	0.00	---	0.02	0.00	0.00	0.02	0.00	0.33
22	0.00	0.01	---	0.00	0.00	0.00	0.13	0.00	0.00	0.14	0.20	0.00
23	0.04	0.00	---	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.04	0.06
24	0.00	0.00	---	0.00	0.00	0.46	0.00	0.00	0.00	0.07	0.10	0.39
25	0.00	0.00	---	0.00	0.00	0.01	0.00	0.81	0.00	0.40	1.62	0.00
26	0.00	0.00	---	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.00
27	---	0.00	0.14	0.20	0.00	0.00	0.00	0.00	0.07	0.01	0.36	0.00
28	---	0.00	1.03	0.00	0.00	0.00	0.00	0.16	0.35	0.00	0.04	0.00
29	1.15	0.00	1.19	0.00	0.93	0.32	0.00		0.00	0.00	0.12	0.00
30	0.47	0.00	0.38	0.08	1.10	0.00	0.00		0.03	0.00	0.01	0.00
31	0.00	0.32		0.00		0.00	0.00		1.64		0.00	
Total Rain	**3.93**	**3.38**	**2.93**	**0.59**	**2.33**	**3.12**	**2.80**	**1.63**	**3.45**	**2.82**	**5.41**	**2.40**
Annual Rainfall Total:												**34.79**
* "---" = gauge offline												

Table C-2. July 2016-June 2017 rainfall data from Wheel Creek HOBO logger (inches)												
Day	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**
1	0.00	0.29	0.74	0.14	0.00	0.03	0.00	0.00	0.06	0.00	0.02	0.00
2	0.00	0.02	0.00	0.01	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.03	0.02	0.00	0.72	0.00	0.00	0.24	0.00	0.00
4	0.66	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.07	0.00
5	0.22	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	1.33	0.10
6	0.00	0.13	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.96	0.05	0.31
7	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.02
8	0.96	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.34	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.23	0.00	0.00	0.00
11	0.00	0.01	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.33	0.00
12	0.00	0.00	0.01	0.00	0.00	0.24	0.02	0.30	0.00	0.00	0.15	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00
14	0.00	0.31	0.00	0.00	0.00	0.00	0.01	0.00	0.57	0.00	0.00	0.00
15	0.00	0.33	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.02	0.00	0.00
16	0.08	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00
17	0.01	0.38	0.00	0.00	0.00	0.69	0.17	0.00	0.00	0.14	0.00	0.00
18	0.02	0.24	0.00	0.00	0.00	0.12	0.01	0.00	0.13	0.00	0.00	0.00
19	0.19	0.01	0.75	0.00	0.08	0.00	0.00	0.00	0.12	0.00	0.03	0.95
20	0.01	0.00	0.04	0.00	0.00	0.00	0.08	0.00	0.00	0.61	0.00	0.01
21	0.03	1.19	0.00	0.17	0.00	0.00	0.01	0.00	0.01	0.02	0.00	0.00
22	0.00	0.01	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.16	0.19	0.00
23	0.08	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.04	0.00
24	0.01	0.00	0.00	0.00	0.00	0.47	0.01	0.00	0.00	0.05	0.09	0.00
25	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.69	0.00	0.42	1.54	0.01
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01	0.00
27	0.00	0.00	0.09	0.22	0.00	0.00	0.00	0.00	0.06	0.00	0.39	0.00
28	0.90	0.00	0.50	0.00	0.00	0.00	0.00	0.16	0.41	0.01	0.05	0.00
29	1.12	0.00	0.77	0.00	0.96	0.26	0.00		0.00	0.00	0.13	0.00
30	0.45	0.00	0.29	0.09	1.17	0.00	0.00		0.03	0.00	0.01	0.00
31	0.01	0.05		0.00		0.00	0.00		1.55		0.00	
Total Rain	**4.75**	**2.97**	**3.19**	**0.70**	**2.40**	**2.92**	**2.65**	**1.49**	**3.23**	**2.70**	**5.38**	**1.40**
											Annual Rainfall Total:	**33.78**

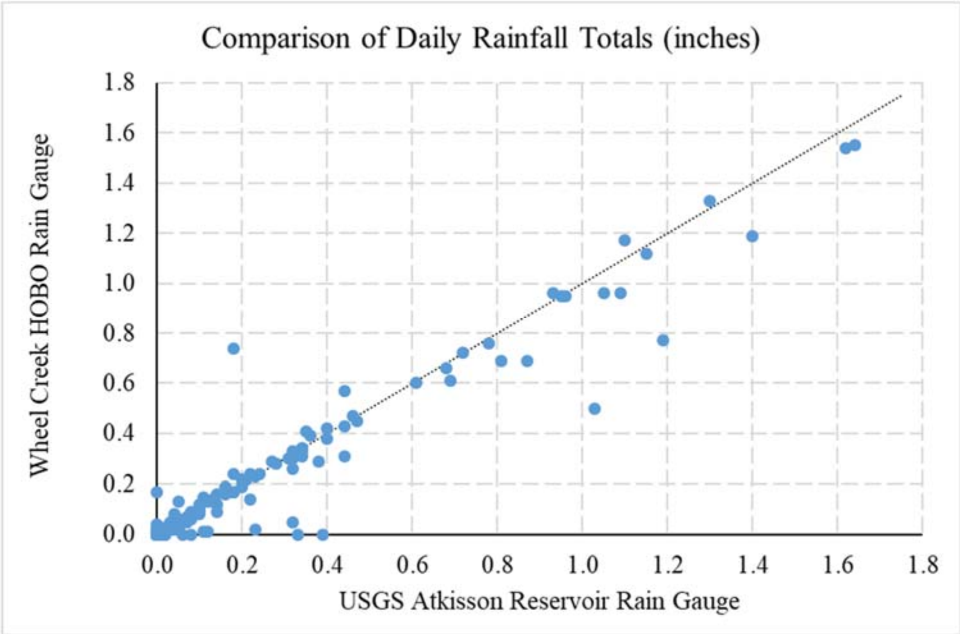

Figure C-1. Comparison of Daily Rainfall Totals for the USGS and Wheel Creek gauges

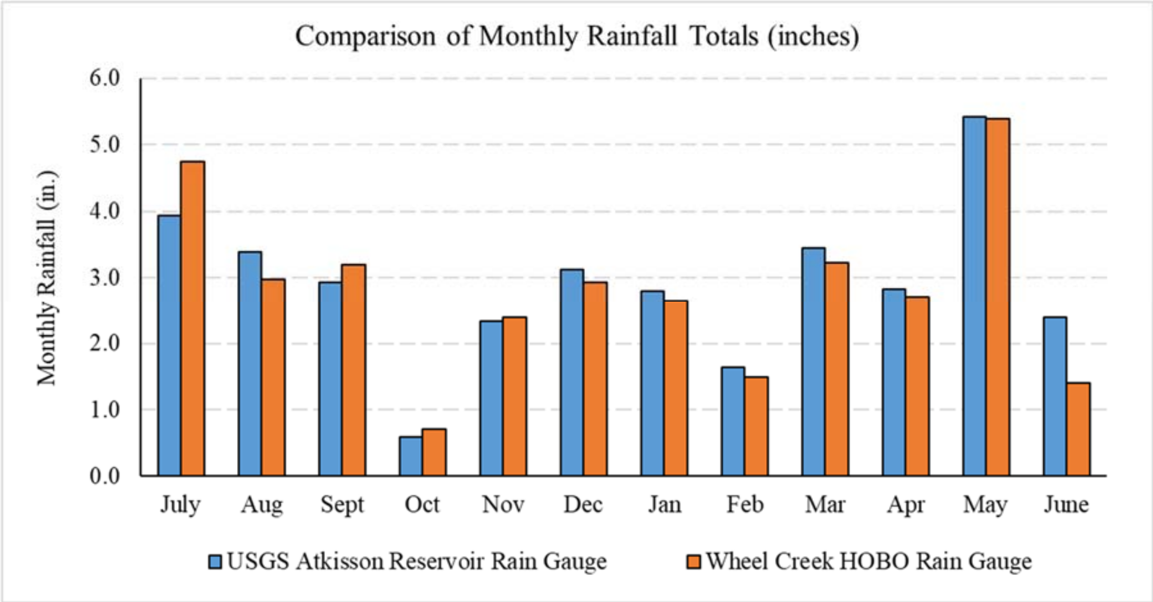

Figure C-2. Comparison of Monthly Rainfall Totals for the USGS and Wheel Creek gauges

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APPENDIX D

TOTAL ANNUAL LOADS AND YIELDS OF POLLUTANTS AT WHEEL CREEK STUDY STATIONS

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Table D-1. Baseflow and storm flow MCs and EMCs, total annual loads, and annual yields (July 2016-June 2017)

Analyte	Station	Storm EMC (mg/L)	Baseflow MC (mg/L)	Annual Storm Load (lbs)	Annual Baseflow Load (lbs)	Annual Total Load (lbs)	Yield (lbs/ac/yr)
Ammonia	WC002	0.014	0.000	10.088	0.000	10.088	0.030
	WC003	0.062	0.009	11.010	0.838	11.847	0.102
	WC004	0.047	0.000	8.722	0.000	8.722	0.224
BOD	WC002	9.713	1.522	6,905.242	597.572	7,502.814	22.376
	WC003	11.878	0.893	2,106.730	84.620	2,191.350	18.826
	WC004	6.394	0.095	1,190.446	6.864	1,197.310	30.700
Chloride	WC002	45.233	81.550	32,157.641	32,012.804	64,170.444	0.492
	WC003	41.806	71.499	7,415.125	6,774.071	14,189.196	0.639
	WC004	52.212	123.272	9,720.289	8,914.497	18,634.786	0.542
Nitrate	WC002	0.518	0.937	368.428	367.649	736.077	2.195
	WC003	0.567	0.597	100.580	56.532	157.112	1.350
	WC004	0.621	1.640	115.685	118.631	234.316	6.008
Nitrate + Nitrite	WC002	0.563	1.862	399.937	731.108	1,131.045	3.373
	WC003	0.626	1.246	110.947	118.058	229.005	1.967
	WC004	0.651	3.299	121.215	238.600	359.814	9.226
Ortho-phosphate	WC002	0.000	0.000	0.000	0.000	0.000	0.000
	WC003	0.000	0.000	0.000	0.000	0.000	0.000
	WC004	0.000	0.000	0.000	0.000	0.000	0.000
TKN	WC002	1.079	0.256	767.057	100.665	867.721	2.588
	WC003	1.027	0.244	182.229	23.147	205.376	1.764
	WC004	0.929	0.249	173.021	17.994	191.016	4.898
Total P	WC002	0.162	0.003	115.463	1.132	116.595	0.348
	WC003	0.232	0.004	41.088	0.388	41.476	0.356
	WC004	0.114	0.004	21.186	0.323	21.509	0.552
TSS	WC002	72.340	1.529	51,428.331	600.206	52,028.537	155.170
	WC003	59.702	4.463	10,589.256	422.801	11,012.057	94.605
	WC004	46.500	0.818	8,656.892	59.140	8,716.032	223.488

Table D-2. Baseflow and storm flow MCs and EMCs, total annual loads, and annual yields for metals (July 2016-June 2017)							
Analyte	**Station**	**Storm EMC (µg/L)**	**Baseflow MC (µg/L)**	**Annual Storm Load (lbs)**	**Annual Baseflow Load (lbs)**	**Annual Total Load (lbs)**	**Yield (lbs/ac/yr)**
Copper	WC002	10.365	0.000	7.369	0.000	7.369	0.022
	WC003	12.401	0.000	2.200	0.000	2.200	0.019
	WC004	12.520	0.000	2.331	0.000	2.331	0.060
Lead	WC002	1.685	0.005	1.198	0.002	1.200	0.004
	WC003	1.958	0.007	0.347	0.001	0.348	0.003
	WC004	1.784	0.000	0.332	0.000	0.332	0.009
Zinc	WC002	34.961	8.881	24.854	3.486	28.341	0.085
	WC003	41.558	11.558	7.371	1.095	8.466	0.073
	WC004	47.331	10.796	8.812	0.781	9.592	0.246

APPENDIX E

TOTAL SEASONAL LOADS OF POLLUTANTS AT WHEEL CREEK STUDY STATIONS

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Table E-1. Baseflow and storm flow MCs and EMCs and total seasonal load (2016-2017)

Sample Year	Season	Station	Storm EMC (mg/L)	Baseflow MC (mg/L)	Seasonal Storm Load (lbs)	Seasonal Baseflow Load (lbs)	Seasonal Total Load (lbs)
Ammonia							
2016	Summer	WC002	0.044	0.000	8.573	0.000	8.573
		WC003	0.000	0.000	0.000	0.000	0.000
		WC004	0.000	0.000	0.000	0.000	0.000
	Fall	WC002	0.000	0.000	0.000	0.000	0.000
		WC003	0.000	0.000	0.000	0.000	0.000
		WC004	0.000	0.000	0.000	0.000	0.000
2017	Winter	WC002	0.000	0.000	0.000	0.000	0.000
		WC003	--	--	--	--	--
		WC004	0.000	0.000	0.000	0.000	0.000
	Spring	WC002	0.014	0.000	2.799	0.000	2.799
		WC003	0.124	0.040	8.088	0.771	8.859
		WC004	0.098	0.000	4.271	0.000	4.271
BOD							
2016	Summer	WC002	11.123	2.266	2180.026	190.182	2370.208
		WC003	8.982	0.872	781.535	22.326	803.861
		WC004	6.642	0.000	394.121	0.000	394.121
	Fall	WC002	7.551	2.535	665.222	252.549	917.771
		WC003	5.979	1.025	265.299	56.570	321.869
		WC004	3.467	0.000	121.866	0.000	121.866
2017	Winter	WC002	4.739	0.000	1074.146	0.000	1074.146
		WC003	--	--	--	--	--
		WC004	1.146	0.000	48.246	0.000	48.246
	Spring	WC002	10.123	1.596	2080.781	141.447	2222.228
		WC003	16.625	0.688	1084.975	13.306	1098.281
		WC004	8.565	0.610	375.048	8.708	383.756
Chloride							
2016	Summer	WC002	35.225	30.821	6903.657	2586.603	9490.259
		WC003	41.606	40.717	3620.011	1042.776	4662.787
		WC004	48.247	45.005	2863.038	721.850	3584.887
	Fall	WC002	27.106	97.988	2388.013	9762.517	12150.530
		WC003	40.198	96.299	1783.781	5316.164	7099.945
		WC004	18.214	149.090	640.219	4319.458	4959.677
2017	Winter	WC002	379.665	100.151	86047.480	11587.802	97635.283
		WC003	--	--	--	--	--
		WC004	240.203	221.024	10113.007	3058.725	13171.733
	Spring	WC002	42.486	91.801	8733.200	8137.393	16870.593
		WC003	42.878	77.802	2798.265	1504.077	4302.342
		WC004	66.219	103.530	2899.792	1478.512	4378.304

Table E-1. (Continued)

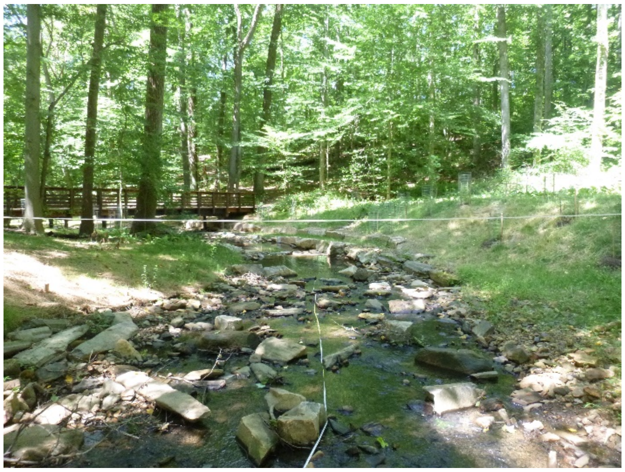
Sample Year	Season	Station	Storm EMC (mg/L)	Baseflow MC (mg/L)	Seasonal Storm Load (lbs)	Seasonal Baseflow Load (lbs)	Seasonal Total Load (lbs)
Nitrate							
2016	Summer	WC002	0.900	1.004	176.445	84.231	260.676
		WC003	0.806	0.666	70.086	17.053	87.140
		WC004	1.221	1.033	72.426	16.567	88.993
	Fall	WC002	0.535	0.906	47.171	90.272	137.443
		WC003	0.712	0.624	31.605	34.443	66.048
		WC004	0.678	2.204	23.816	63.840	87.655
2017	Winter	WC002	0.633	0.864	143.437	99.973	243.410
		WC003	--	--	--	--	--
		WC004	0.660	1.931	27.804	26.722	54.527
	Spring	WC002	0.459	0.994	94.295	88.150	182.445
		WC003	0.387	0.431	25.271	8.326	33.597
		WC004	0.369	1.079	16.174	15.412	31.586
Nitrate + Nitrite							
2016	Summer	WC002	0.935	1.966	183.210	164.982	348.193
		WC003	0.806	1.414	70.086	36.205	106.291
		WC004	1.221	2.058	72.426	33.015	105.441
	Fall	WC002	0.535	1.799	47.171	179.204	226.375
		WC003	0.712	1.300	31.605	71.760	103.365
		WC004	0.678	4.461	23.816	129.239	153.054
2017	Winter	WC002	0.633	1.738	143.437	201.103	344.540
		WC003	--	--	--	--	--
		WC004	0.743	3.862	31.298	53.450	84.747
	Spring	WC002	0.515	1.987	105.943	176.084	282.027
		WC003	0.504	0.866	32.888	16.745	49.632
		WC004	0.427	2.157	18.684	30.803	49.487
Orthophosphate							
2016	Summer	WC002	0.000	0.000	0.000	0.000	0.000
		WC003	0.000	0.000	0.000	0.000	0.000
		WC004	0.000	0.000	0.000	0.000	0.000
	Fall	WC002	0.000	0.000	0.000	0.000	0.000
		WC003	0.000	0.000	0.000	0.000	0.000
		WC004	0.000	0.000	0.000	0.000	0.000
2017	Winter	WC002	0.000	0.000	0.000	0.000	0.000
		WC003	--	--	--	--	--
		WC004	0.000	0.000	0.000	0.000	0.000
	Spring	WC002	0.000	0.000	0.000	0.000	0.000
		WC003	0.000	0.000	0.000	0.000	0.000
		WC004	0.000	0.000	0.000	0.000	0.000

Table E-1. (Continued)

Sample Year	Season	Station	Storm EMC (mg/L)	Baseflow MC (mg/L)	Seasonal Storm Load (lbs)	Seasonal Baseflow Load (lbs)	Seasonal Total Load (lbs)
TKN							
2016	Summer	WC002	0.850	0.359	166.532	30.119	196.650
		WC003	0.737	0.347	64.114	8.888	73.003
		WC004	0.701	0.415	41.593	6.658	48.252
	Fall	WC002	0.837	0.313	73.708	31.192	104.899
		WC003	0.847	0.155	37.573	8.552	46.125
		WC004	0.882	0.222	30.984	6.429	37.414
2017	Winter	WC002	0.415	0.181	94.030	20.983	115.013
		WC003	--	--	--	--	--
		WC004	0.628	0.067	26.450	0.924	27.374
	Spring	WC002	1.181	0.185	242.774	16.369	259.143
		WC003	1.249	0.235	81.501	4.550	86.051
		WC004	1.059	0.194	46.372	2.775	49.146
Total Phosphorous							
2016	Summer	WC002	0.142	0.012	27.855	1.037	28.892
		WC003	0.109	0.011	9.508	0.281	9.790
		WC004	0.085	0.015	5.037	0.244	5.281
	Fall	WC002	0.105	0.000	9.253	0.000	9.253
		WC003	0.396	0.000	17.551	0.000	17.551
		WC004	0.099	0.000	3.483	0.000	3.483
2017	Winter	WC002	0.028	0.000	6.271	0.000	6.271
		WC003	--	--	--	--	--
		WC004	0.039	0.000	1.631	0.000	1.631
	Spring	WC002	0.181	0.000	37.275	0.000	37.275
		WC003	0.176	0.000	11.497	0.000	11.497
		WC004	0.138	0.000	6.045	0.000	6.045
TSS							
2016	Summer	WC002	38.041	2.320	7455.485	194.696	7650.181
		WC003	41.730	11.984	3630.835	306.910	3937.745
		WC004	13.057	2.277	774.843	36.525	811.368
	Fall	WC002	26.792	3.953	2360.404	393.816	2754.219
		WC003	31.502	0.000	1397.874	0.000	1397.874
		WC004	41.419	0.000	1455.858	0.000	1455.858
2017	Winter	WC002	4.169	0.000	944.826	0.000	944.826
		WC003	--	--	--	--	--
		WC004	14.685	0.914	618.284	12.650	630.934
	Spring	WC002	88.930	0.000	18280.070	0.000	18280.070
		WC003	83.954	0.000	5478.881	0.000	5478.881
		WC004	63.499	0.000	2780.681	0.000	2780.681

Table E-2. Baseflow and storm flow MCs and EMCs and total seasonal load (2016-2017)

Sample Year	Season	Station	Storm EMC (µg/L)	Baseflow MC (µg/L)	Seasonal Storm Load (lbs)	Seasonal Baseflow Load (lbs)	Seasonal Total Load (lbs)
Copper							
2016	Summer	WC002	6.5	0.0	1.280	0.000	1.280
		WC003	9.4	0.0	0.820	0.000	0.820
		WC004	7.7	0.0	0.459	0.000	0.459
	Fall	WC002	9.7	0.0	0.858	0.000	0.858
		WC003	9.0	0.0	0.398	0.000	0.398
		WC004	11.7	0.0	0.412	0.000	0.412
2017	Winter	WC002	5.6	0.0	1.268	0.000	1.268
		WC003	--	--	--	--	--
		WC004	8.7	0.0	0.364	0.000	0.364
	Spring	WC002	11.2	0.0	2.292	0.000	2.292
		WC003	15.7	0.0	1.022	0.000	1.022
		WC004	15.0	0.0	0.655	0.000	0.655
Lead							
2016	Summer	WC002	0.0	0.0	0.000	0.000	0.000
		WC003	0.0	0.0	0.000	0.000	0.000
		WC004	0.0	0.0	0.000	0.000	0.000
	Fall	WC002	0.4	0.0	0.033	0.000	0.033
		WC003	1.1	0.0	0.047	0.000	0.047
		WC004	0.6	0.0	0.021	0.000	0.021
2017	Winter	WC002	0.4	0.0	0.079	0.000	0.079
		WC003	--	--	--	--	--
		WC004	1.1	0.0	0.046	0.000	0.046
	Spring	WC002	2.2	0.0	0.461	0.002	0.463
		WC003	3.3	0.0	0.212	0.001	0.213
		WC004	3.2	0.0	0.142	0.000	0.142
Zinc							
2016	Summer	WC002	23.1	7.2	4.524	0.600	5.124
		WC003	27.6	7.6	2.401	0.196	2.597
		WC004	23.5	7.9	1.394	0.127	1.521
	Fall	WC002	25.4	7.8	2.239	0.781	3.020
		WC003	32.5	9.0	1.441	0.496	1.937
		WC004	49.5	11.9	1.740	0.346	2.086
2017	Winter	WC002	20.5	11.6	4.645	1.339	5.984
		WC003	--	--	--	--	--
		WC004	26.9	13.8	1.132	0.191	1.324
	Spring	WC002	39.1	8.3	8.035	0.740	8.775
		WC003	52.5	22.8	3.423	0.441	3.864
		WC004	55.4	10.2	2.427	0.146	2.573



WHEEL CREEK GEOMORPHIC ASSESSMENT POST-RESTORATION YEAR 1 FINAL REPORT

December 20, 2017

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WHEEL CREEK
GEOMORPHIC ASSESSMENT
POST-RESTORATION YEAR 1 FINAL REPORT

Prepared for:

Harford County
Department of Public Works
Division of Highways and Water Resources
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Columbia, Maryland 21045

December 20, 2017

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1.0 INTRODUCTION

Harford County Department of Public Works (DPW) has been undertaking the restoration of the Wheel Creek watershed, which is located in the Bush River Basin in the central portion of Harford County near Bel Air (Figure 1-1). The restoration project is the result of previous planning efforts including the Bush River Watershed Restoration Strategy (WRAS), the Bush River Watershed Management Plan in 2003, and more recently, the Wheel Creek Watershed Assessment completed in 2008.

Restoration efforts in this watershed began in 2012 with restoration/retrofit of a stormwater management pond (Pond A), located at the Gardens of Bel Air, which was completed in December of 2012. A second project, the Calvert's Walk stream restoration project, began in early 2013 and was completed that April. In 2015, two more storm-water management ponds were implemented (Pond C in August and Pond D in December). The final phase of retrofits was completed in early 2017. This included the Lower Wheel Creek stream restoration, which began in September 2016, and an additional stormwater management pond (Pond E).

As part of implementing the restoration efforts, the County was awarded funds from a Local Government Implementation Grant through the Chesapeake and Atlantic Bays 2010 and 2016 Trust Funds. Under the grant proposal, the County planned to implement a total of four stormwater retrofits and five stream restoration projects to improve water quality, decrease stormwater discharges, and improve instream habitat.

Beginning in 2009, the County initiated monitoring to demonstrate measureable reductions of sediment and nutrients, improvement in physical stability and instream habitat, and improvement in fish and benthic macroinvertebrates communities. As a collaborative monitoring effort, Harford County DPW, Maryland Department of Natural Resources (DNR), the United States Geologic Survey (USGS), and two consulting firms (KCI Technologies and Versar, Inc.) have performed select data collection activities. The study design was developed to compare pre-construction conditions (i.e., baseline conditions) to future post-construction restoration conditions. This report focuses on five years of geomorphic monitoring, conducted by KCI and Versar. Data generated by other project partners includes:

- USGS – flow gaging at the downstream end of Wheel Creek (5-minute interval discharge record);
- Maryland DNR (Up to July 2016)/Versar (July 2016 to present) – flow gaging at three stations, one at Wheel Road and two upstream on the eastern tributary at Cinnabar Lane and Wheel Court (5-minute interval discharge record);
- Maryland DNR MBSS – Biological and physical habitat data; and
- Versar – Storm runoff water chemistry and water quality monitoring including nutrient and sediment data at three stations, one at Wheel Road and two upstream on the eastern tributary at Cinnabar Lane and Wheel Court (pollutant loads for the measured parameters for each sampled event)

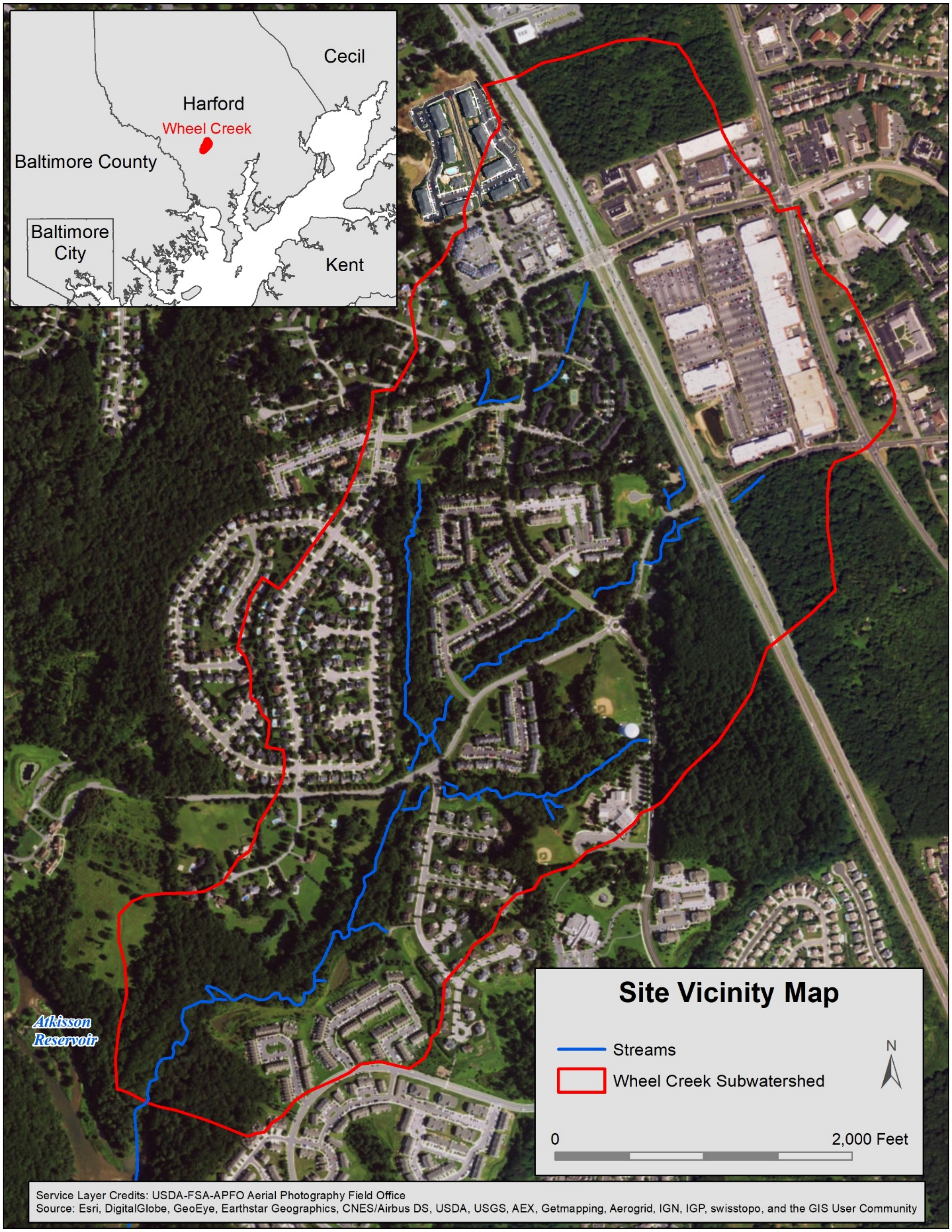

Figure 1-1. Site vicinity map

- Harford County DPW – Baseflow nutrient and sediment data at three stations, one at Wheel Road and two upstream on the eastern tributary at Cinnabar Lane and Wheel Court, as well as nutrient synoptic stream chemistry sampling watershed-wide and in a nearby reference watershed.

Assessment and monitoring of the physical geomorphologic conditions was initially performed by KCI in 2010 (Pre-Restoration Year 1) to evaluate baseline conditions and was continued by Versar in 2012 (Pre-Restoration Year 2), 2013 (Pre-Restoration Year 3), 2015 (Pre-Restoration Year 4), and 2017 (Post-Restoration Year 1). The geomorphic monitoring program was designed to assess the geomorphic stability of the stream channels in the Wheel Creek watershed as they respond to restoration activities. The geomorphic monitoring includes surveying and analyzing monumented cross-sections and longitudinal profiles at four (4) reaches (Pre-Restoration Years 1 through 4 and Post-Restoration Year 1), monitoring bankpins and scour chains (Pre-Restoration Year 1 through 4 only), mapping substrate facies (Pre-Restoration Year 1 only), and evaluating substrate particle size distribution (Pre-Restoration Years 1 through 4 and Post-Restoration Year 1). The methods evaluate bed and bank stability, channel profile, and bed features. For a complete description of the Year 1 Study see *Wheel Creek Watershed Restoration Project, Pre-Construction Monitoring, Baseline Conditions, 2009-2011* (KCI, 2012). For a complete description of the Year 2, Year 3, and Year 4 Studies see *Wheel Creek Geomorphic Assessment Year 2* (Versar, 2013), *Wheel Creek Geomorphic Assessment Year 3* (Versar, 2014) and *Wheel Creek Geomorphic Assessment Year 4* (Versar, 2015) . This report focuses on continued geomorphic monitoring, including a comparison of data collected during Pre-Restoration Years 1, 2, 3, 4, and Post-Restoration Year 1.

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2.0 METHODOLOGIES

2.1 GEOMORPHIC ASSESSMENT

The primary goal of the geomorphic monitoring is to assess the geomorphic stability of the stream channels in the Wheel Creek watershed as they respond to restoration activities. Assessment techniques include a survey of permanently-monumented channel cross-sections, a longitudinal profile survey, particle size analysis, substrate facies mapping (Pre-Restoarion Year 1 only), and assessment of bank pins and scour chains (Pre-Restoration Years 1 through 4 only). In 2010, four (4) assessment reaches (Figure 2-1) were established by KCI for geomorphic monitoring based on the following treatments:

1. within a proposed stream stabilization reach (WC01);
2. downstream of a stream stabilization reach and BMP retrofit location (WC02);
3. downstream of a BMP retrofit location only (WC03); and
4. a control site with no proposed restoration activities (WC04).

These reaches were re-surveyed by Versar in 2012, 2013, 2015, and 2017 to provide additional monitoring data. Cross-sectional and longitudinal profile surveys were first conducted to establish baseline conditions of channel geometry and slope. Subsequent survey data can be compared to the baseline data to determine whether lateral or vertical migration of the channel is occurring and document any changes that have occured in the restored reaches. Bank and bed pins are monitored to determine rates of potential bank and channel bed erosion or aggradation, while scour chains are used to quantify the extent of bed material scouring. The bank and bed pins along with the scour chains have been discontinued from the monitoring following Pre-Restoration Year 4 (2015). Pebble counts are conducted to assess substrate particle size distribution and track changes in channel roughness. Detailed methods are described below.

2.1.1 Longitudinal Profile and Cross-sectional Surveys

KCI installed and surveyed three (3) benchmark monuments at each reach during the initial baseline monitoring effort (2010) to establish consistent survey elevations from year to year, as well as start and end points for each survey reach. Two benchmarks (one concrete monument and one capped iron rebar pin) were placed on either side of the channel, whereby a measuring tape run from the left bank pin to the right bank monument marks the starting point (i.e., station 0+00) in the channel for the longitudinal profile. The concrete monument was set in 2-inch PVC piping to a depth of 30 inches, with a rounded stove bolt set in the concrete to establish the monumented benchmark elevation, which will be used to compare longitudinal profiles over time. A third monument (capped iron rebar) was placed at the upstream end of the reach to mark the end of the survey reach. Versar re-surveyed these benchmarks at WC03 and WC04 during the Post-Restoration Year 1 effort to enable overlays between past surveys.

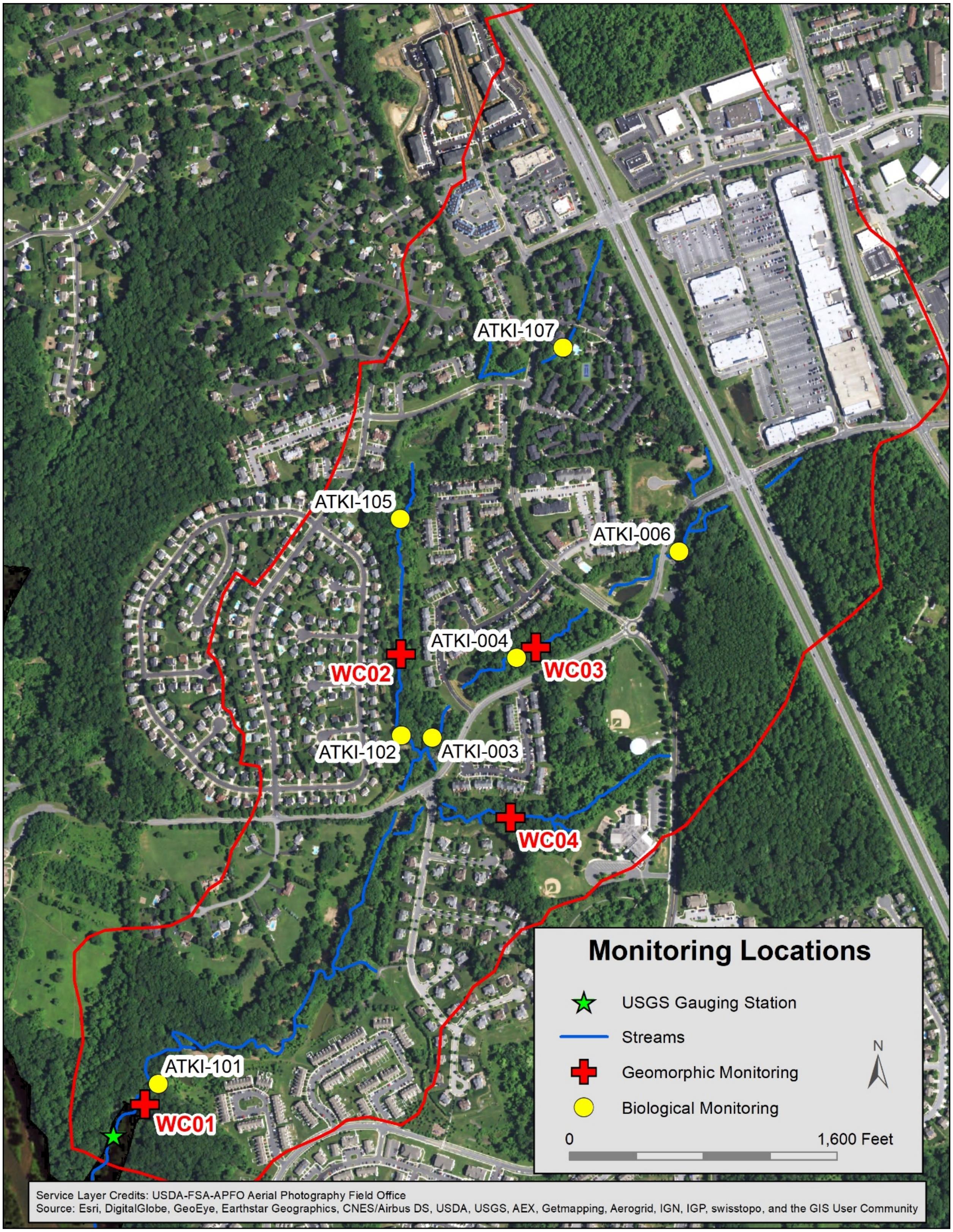

Figure 2-1. Wheel Creek monitoring locations

Versar re-established reaches WC01 and WC02 in 2017 for Post-Restoration Year 1 monitoring. Three (3) benchmark monuments were again installed at both reaches. Two capped iron rebar monuments were installed on each side of the channel to mark the starting point of the new longitudinal profile (i.e., station 0+00). An additional capped iron rebar monument was installed upstream marking the end of the longitudinal profile.

A longitudinal profile of each reach was surveyed using a laser level, calibrated stadia rod, and 300-foot measuring tape following the procedure outlined in Harrelson et al. (1994). The profiles were established along the centerline of each bankfull channel and included a survey of breakpoints in and between bed features and delineation of riffle, run, pool, and glide features. A survey of the bankfull elevation (where discernible), top of bank, and water surface was also performed. At each site where instream restoration activities did not occur (WC03 and WC04), the plotted Post-Restoration Year 1 longitudinal profile was overlaid with the plots from Pre-Restoration Years 1 through 4. These plots enable comparisons between years and are used to track changes that occur in the bed sequences and channel slopes. At the two sites where instream restoration occurred (reaches WC01 and WC02), the plotted profiles from Pre-Restoration Years 1 through 4 were overlaid and the Post-Restoration Year 1 plotted profiles were compared.

In order to establish locations where fluvial geomorphic characteristics of the channel could be measured and compared from one year to the next for assessing bed and bank stability, KCI established permanent cross-sections at two (2) locations within each monitoring reach during Pre-Restoration Year 1; one located on a meander bend and one within a riffle feature. KCI established monuments (one concrete and one capped iron rebar) on either side of the channel to mark the cross-section locations and benchmark elevations. Concrete monuments were set in 2-inch PVC piping to a depth of 30 inches, with a rounded metal stove bolt set in the concrete to mark the monumented elevation. Wherever possible, the monuments were set flush to the ground surface for safety concerns, and the location of each monument was recorded using a GPS unit capable of sub-meter accuracy. In Post-Restoration Year 1 (2017), reaches WC01 and WC02 were re-established with new benchmarks following completion of restoration activities. Reaches WC03 and WC04 are still monumented to the original benchmarks installed in Pre-Restoration Year 1 (2010) since no instream restortation occurred.

Permanent cross-sections were established and surveyed during Pre-Restoration Years 1, 2, 3, 4, and Post-Restoration Year 1 within each reach at profile stations as shown in Table 2-1. Stationing differed slightly at several stations due to channel migration over time or as a result of re-installing a cross-section when instream restoration has occured. Cross-sections located in reaches WC01 and WC02 were re-established post-restoration. The same methods were used to establish the new cross-sections in these reaches, although the corresponding station on the longitundiual profile will not be comparable to previous years of pre-restoration surveying.

Table 2-1. Cross-sectional survey locations

Reach	Profile Station (Pre-Year 1)	Profile Station (Pre-Year 2)	Profile Station (Pre-Year 3)	Profile Station (Pre-Year 4)	Profile Station (Post-Year 1)	Feature
WC01*	2+30	2+30	2+29	2+29	2+24	Riffle
	2+95	2+95	2+95	2+95	2+71	Meander/Pool
WC02*	1+37	1+38	1+38	1+38	0+74.5	Riffle
	3+24	3+24	3+25	3+24	1+10	Pool
WC03	1+55	1+57	1+56	1+55	1+56	Riffle
	2+07	2+08	2+12	2+07	2+08	Meander/Run
WC04	1+08	1+08	1+08	1+08	1+10	Meander/Pool
	1+68	1+68	1+68	1+68	1+68	Riffle

*Cross-Sections re-established during Post-Restoration Year 1

During Post-Restoration Year 1, Versar resurveyed the cross-sections using a laser level, calibrated stadia rod, and measuring tape following the procedure outlined in Harrelson et al. (1994). The cross-sectional surveys captured features of the floodplain, monuments, and all pertinent channel features including:

- Top of bank
- Bankfull elevation
- Edge of water
- Limits of point and instream depositional features
- Thalweg
- Floodprone elevation

Longitudinal profile and cross-sectional data were entered into *The Reference Reach Spreadsheet* version 4.3L (ODNR 2012) for data analysis and graphical interpretation. Profile and cross-sectional data collected in 2010, 2012, 2013, 2015 and 2017 provide five years of data to which subsequent monitoring events will be overlaid and/or compared to assess changes in channel dimension, pattern, and profile.

For the purpose of this report, bankfull elevations were selected based upon bankfull indicators observed in the field. Channel geometry and cross-sectional areas were calculated using *The Reference Reach Spreadsheet* (ODNR 2012). Because bankfull indicators are not always easily discernible from year to year and best professional judgment is often required to determine bankfull elevations, top of bank features were also measured. Top of low bank cross-sectional areas were also calculated and can be utilized for future monitoring events to generate hydraulic geometry values that are more directly comparable between each monitoring effort.

2.1.2 Particle Size Analysis

Channel substrate composition (e.g., gravel, sand, silt) is an important aspect of a stream's biological and geomorphic character. The substrate size and complexity affects the stream's available habitat for benthic fauna and determines a channel's roughness, which influences the channel flow characteristics. To quantify the distribution of channel substrate particle sizes within the study area, modified Wolman pebble counts (Wolman 1954; Harrelson et al. 1994) were performed. A total of three (3) pebble counts were conducted within each monitoring reach; feature-specific pebble counts were conducted at each cross section location within the cross-sectional bed feature (typically riffles), and a weighted pebble count was conducted throughout the entire reach based on the proportion of bed features (e.g., riffle, run, pool, glide) present within the survey reach. Feature-specific pebble counts were performed via 10 evenly-spaced transects positioned throughout the survey feature, and 10 particles (spaced as evenly as possible) were measured across the bankfull channel of each transect for a total of 100 particles. The weighted (proportional) pebble count was conducted at 10 transects positioned throughout the entire reach based on the proportion of bed features, and 10 particles (spaced as evenly as possible) were measured across the bankfull channel of each transect for a total of 100 particles. For both types of counts, particles were chosen without visual bias by reaching forth with an extended finger into the stream bed while looking away and choosing the first particle that comes in contact with the sampler's finger. All particles were then measured across the intermediate axis using a grav-elometer and resultant data were entered into *The Reference Reach Spreadsheet* (ODNR 2012). The results of each weighted pebble count were used to determine the median particle size (i.e., D_{50}) of the specific reach. Additionally, the D_{84} was calculated from the feature pebble counts to determine the particle size that 84 percent of the sample is of the same size or smaller. The D_{84} particles were used in calculating channel velocity and discharge. Results from Versar's Post-Restoration Year 1 evaluations were compared to those found during the previous years of monitoring to evaluate changes in channel substrate composition.

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3.0 RESULTS AND DISCUSSION

3.1 FLUVIAL GEOMORPHIC ASSESSMENT

3.1.1 Longitudinal Profiles and Cross-sectional Surveys

The first year of post-restoration baseline longitudinal profile and cross-sectional surveys were completed between June 14th and June 26th, 2017. While performing the longitudinal profile, bed features including riffles, runs, pools, glides, bankfull indicators (where readily discernible), and water surface were noted to sufficiently assess conditions. The longitudinal profile data were analyzed to calculate the water surface slope and proportion of bed features for each monitoring reach (Table 3-1). These data will be compared to previous and subsequent annual monitoring data to track potential changes in the overall channel slope. Refer to Appendix A for photographs depicting the overall site conditions during the Post-Restoration Year 1 baseline survey. Graphical depictions of each profile are presented in Appendix B. In addition, each surveyed profile was plotted, but only overlain and compared to the Pre-Restoration Years 1, 2, 3, and 4 profiles at WC03 and WC04 (Appendix C) and will be compared to subsequent annual surveyed profiles in order to assess changes occurring in the bed structure. Due to instream restoration activities, WC01 and WC02 post-restoration overlays do not share the same monuments as pre-restoration. Therefore, separate overlays were created for these reaches.

Table 3-1. Results of longitudinal profile survey – Post-Restoration Year 1

Reach	Length (ft)	Slope	Proportion of Features			
			Riffle	Run	Pool	Glide
WC01*	490	2.6%	47.5%	7.6%	36.6%	8.3%
WC02*	321.5	2.3%	57.3%	6.3%	28.5%	7.9%
WC03	306	1.7%	52.4%	13.6%	23.5%	10.5%
WC04	300	3.5%	48.2%	24.3%	14.0%	13.5%

*Profiles re-established during Post-Restoration Year 1

Cross-sectional surveys were analyzed at each of the eight permanent monitoring locations to determine bankfull width, mean depth, width/depth ratio, and overall cross-sectional area during baseline conditions. Since bankfull elevation is based on field indicators and can be somewhat subject to determine in the field, top-of-bank elevation was also calculated and will be utilized to track changes in the cross-sectional dimensions listed below. Results of the cross-sectional measurements are included in Table 3-2 and graphical depictions of each section are presented in Appendix B. In addition, each surveyed section was plotted, overlain (where appropriate) and compared to the pre-construction year 1, 2, 3, and 4 graphs (Appendix C) and will be compared to subsequent annual cross-section graphs in order to assess changes to channel dimensions post-restoration.

Table 3-2. Results of cross-sectional survey analysis – Post-Restoration Year 1

Reach	Station	Feature	Bankfull Width (ft)	Mean Depth (ft)	Width/ Depth Ratio	Entrench-ment Ratio	Bankfull Area (ft^2)	Top of Bank Area (ft^2)
WC01*	2+24	Crossover/Riffle	20.7	0.8	26.8	1.7	16.0	164.4
	2+71	Meander/Pool	21.3	2.0	10.7	1.4	42.6	269.7
WC02*	0+74.5	Pool	13.6	1.3	10.2	1.3	18.2	49.0
	1+10	Crossover/Riffle	11.6	0.5	24.6	1.3	5.5	38.6
WC03	1+56	Riffle	7.3	0.9	8.6	1.7	7.3	35.0
	2+08	Meander/Run	9.8	0.9	12.2	2.7	9.8	61.5
WC04	1+10	Meander/Pool	20.6	0.4	51.3	1.5	8.3	99.8
	1+68	Crossover/Riffle	10.4	0.5	22.3	1.4	4.8	54.8

*Cross-Sections were re-established during Post-Restoration Year 1

3.1.2 Particle Size Analysis

The results of the pebble count data collected during the Post-Restoration Year 1 monitoring are shown in Table 3-3. Reachwide and riffle surface pebble counts indicate a D_{50} median particle size class ranging from very fine gravel to very coarse gravel across all sites. Meander feature surface pebble counts indicate a D_{50} ranging from very fine gravel to medium gravel, due to pool features yielding smaller particles that is especially evident at the restored WC-02 meander/pool cross section. Riffle surface and reachwide D_{84} size classes range from very coarse gravel to small cobble at all sites, with the largest particles found at site WC01. Meander feature surface pebble counts at all sites indicate a D_{84} median particle size class ranging from medium gravel to very coarse gravel. Complete particle size distribution charts are included in Appendix B.

Table 3-3. Particle size distribution – Post-Restoration Year 1

Riffle Feature Surface			*Meander Feature Surface*			*Reachwide*		
Measure	**Size (mm)**	**Size Class**	**Measure**	**Size (mm)**	**Size Class**	**Measure**	**Size (mm)**	**Size Class**
*WC01**								
D_{50}	52	very coarse gravel	D_{50}	11	medium gravel	D_{50}	25	coarse gravel
D_{84}	120	small cobble	D_{84}	57	very coarse gravel	D_{84}	90	small cobble
*WC02**								
D_{50}	26	coarse gravel	D_{50}	4.3	very fine gravel	D_{50}	16	medium gravel
D_{84}	85	very coarse gravel	D_{84}	19	medium gravel	D_{84}	62	very coarse gravel
WC03								
D_{50}	26	coarse gravel	D_{50}	17	medium gravel	D_{50}	16	medium gravel
D_{84}	59	very coarse gravel	D_{84}	61	very coarse gravel	D_{84}	50	very coarse gravel
WC04								
D_{50}	43	coarse gravel	D_{50}	12	medium gravel	D_{50}	21	medium gravel
D_{84}	99	small cobble	D_{84}	26	coarse gravel	D_{84}	68	very coarse gravel

*Profile and Cross-sections re-established during Post-Restoration Year 1

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4.0 COMPARISONS BETWEEN YEARS

4.1 WC01

This site exhibited the most drastic changes in longitudinal profile over the fours years of baseline monitoring (2010-2015; Figure C-1). At the downstream-most part of the reach, the stream's thalweg followed along the left bank outside bend during the first year of survey with a large mid-channel bar separating the thalweg from a cutoff channel along the right bank. During the second and third years of monitoring (2012, 2013), the thalweg followed what had been the cutoff channel along the right bank and the previous thalweg channel had only minimal flows. During the fourth year of survey (2015) the thalweg continued to follow the channel along the right bank. Furthermore, a large tree along the left bank fell and is now perpendicularly positioned in the stream through this section. The tree has caused the stream to widen and flow over most of the mid-channel bar; the outside left bend channel however, is now completely dry. At the upstream-most part of the reach, the stream's pattern also changed. Stationing differed from above Cross-section 2 (Station 2+95) to the end of the reach. During the first year of monitoring (2010), the reach was 400 feet from top to bottom, but during all other years the reach was 420 feet in length. Sinuosity above Cross-section 2 likely increased, adding length to the profile.

Changes in the cross-sections were also observed at WC01 between the four years of pre-restoration survey (Figures C-7, C-8). Bed scour was observed at Cross-section 1 (Crossover Riffle at Station 2+29) especially near the right bank between Pre-Restoration Years 1 and 2, while deposition is apparent near the left bank between Pre-Restoration Years 2 and 3. During Pre-Restoration Year 4 of monitoring, continuted deposition was observed and the cross-section once again closely resembles that of Pre-Restoration Year 1. Significant bank erosion and undercutting along the left bank (almost 6 feet) was observed at Cross-section 2 (Meander Bend at Station 2+95) during both second and third years' monitoring (2012, 2013). Between Pre-Restoration Years 3 and 4 continued erosion occurred along the left bank increasing the depth of undercutting. Eroded sediment has caused slight deposition along the left stream bed. This has resulted in increases, from Pre-Restoration Year 1, of bankfull cross-sectional area and top of bank cross-sectional area at this station. Between Pre-Restoration Years 1 and 2, a side-bar formed on the right bank, burying the scour chain at this cross-section. The scour chain was not found during Pre-Restoration Years 3 and 4 of monitoring. In addition, the thalweg pattern changed between Pre-Restoration Years 1 and 2 so that it is no longer perpendicular to the permanently monumented cross-section markers at this location.

The first year of post-restoration monitoring was completed in 2017. WC01 reach under-went an instream restoration and a new longitudinal profile with two cross-sections were selected and monitored for baseline conditions. Cross-section 1 was placed in a crossover riffle at Station 2+24, while cross-section 2 was placed at a meander bend/pool at Station 2+71. The longitudinal profile extends 490 feet through the restored reach in Harford Glen. The survey of the longitudinal profile consisted of large riffle and pool features. Approximately 47.5% of the reach was riffle and 36.6% was pool. The slope of the reach was high at 2.6%. The cross-sections featured stable banks exhibiting no erosion. Cross-section 1 at Station 2+24 has a defined bench and access to a small floodplain as the banks have been graded back during construction (Figure C-9). Cross-section 2 at Station 2+71 exhibits the same flood plain on the right bank in addition to a point bar, while the left bank is heavily armoured by boulders (Figure C-10).

At WC01, D_{50} particle size classes remained the same between all four years of pre-restoration study at both Cross-sections, and reachwide (Table C-3). D_{84} particle size classes changed between Years 1 and 2, coarsening at Cross-section 1 (Crossover Riffle at Station 2+29) from medium to large cobble, and becoming slightly finer at Cross-section 2 (Meander Bend at Station 2+95) from medium to small cobble. Although D_{84} classes at Cross-section 2 were unchanged between Years 2 and 3 they transformed during the fourth year of study, increasing from small cobble to medium cobble. Reachwide particle size class fluxtuated between large cobble during Year 1, to medium cobble during Year 2 and back to large cobble during Years 3 and 4. In the first year of post restoration (2017), the reachwide D_{84} decreased to small cobble. The new crossover riffle at Station 2+24 had a D_{84} of small cobble and the new meander bend/pool at Station 2+71 had a D_{84} of very coarse gravel.

4.2 WC02

Significant changes in profile were not observed at WC02 over the four years of pre-restoration study. The most noticeable change is a pool feature once approximatly at Station 1+00 changed to Station 0+80 (Figure C-11). Reach length remained constant and stream slope measurements were fairly consistent overall. Feature porportions within the reach have fluctuated from year to year. While the percentage of glides increased from 0% to 16.7% between Pre-Restoration Years 1 and 2, the percentage of pools has declined each year. During the fourth year (2015) 25.5% of the surveyed reach was classified as pools and glides, the lowest percentage since monitoring began. In contrast, riffles and runs made up 74.5% of the surveyed reach which was the greatest percentage of all four years (Table C-1).

Following Pre-Restoration Year 1, bed aggradation occurred at Cross-section 1 (Crossover Riffle at Station 1+38), but banks here remained relatively stable (Figure C-11). There has been little change between the third and fourth year of pre-restoration study. Conversely, channel scour occurred at Cross-section 2 (Meander Bend at Station 3+24), as well as slight erosion of the upper portion of the right bank (Figure C-13). At this station, a bankfull bar exists along the left bank which showed little change between Pre-Restoration Years 2 and 3 of the study. However, during the fourth year of pre-restoration monitoring slight degradation can be seen along the left bank and bar.

In the first year of post-restoration monitoring, WC02 reach consisted of 57.3% riffles and 28.5 % pools (Table C-1). This reach underwent instream restoration that has straightened the channel causing the meander bend cross-section to be placed in a straight pool. Overall, this reach was still somewhat lacking access to an immediate floodplain but the banks were stable and well vegetated despite being steep and high. The entrenchment ratio was a low 1.3, indicating the stream is confined within the banks (Appendix B). The stream was predominately long riffles and grade control steps into long/wide pools. Cross-section 1 was newly monumented in a pool at Station 0+74.5 (Figure C-12) and cross-section 2 was monumented at Station 1+10 in a crossover riffle (Figure C-14). Both cross-sections exhibit no erosion and have stable banks.

D_{50} particle size classes remained the same between all four years of pre-restoration study at both cross-sections. The reachwide D_{50} for Pre-Restoration Years 2 and 3 were categorized as coarse gravel which is slightly finer than the very coarse gravel observed in Pre-Restoration Years 1 and 4 (Table C-3). D_{84} particle size classes became slightly finer at both cross-sections, diminishing from medium-sized cobble to small cobble between the first and second years of pre-restoration study. Furthermore, both cross-section D_{84} classes coarsened between Pre-Restoration Years 3 and 4 from small cobble to medium cobble. Although reachwide D_{84} particle sizes also reduced between Pre-Restoration Years 1 and 2, particles increased back to medium-sized cobble in Pre-Restoration Year 3 and remained during Pre-Restoration Year 4. In the first year of post restoration study (2017), the reachwide D_{84} decreased to medium gravel. The new crossover riffle at Station 1+10 had a D_{84} of very coarse gravel and the new meander bend/pool at Station 0+74.5 had a D_{84} of medium gravel.

4.3 WC03

Pool and glide features have previously dominated reach WC03, as 65.6% and 67.5% of the reach was made up of pools and glides during Pre-Restoration Years 1 and 2, respectively. During Pre-Restoration Year 3, however, riffles and runs made up more than half (53.1%) of the reach (Table C-1). Pools and glides were dominant during Pre-Restoration Year 4 (58.5%). Changes in longitudinal profile were noted between the four years' of pre-restoration study, most notably the deepening of most pools reachwide between the first two years (Figure C-5). Pool depth has stayed fairly consistent from Pre-Restoration Year 2 through Year 4 with the exception of the pool feature at station 1+00 which has deepened about a foot.

In 2017, WC03 consisted of 52.4% riffles and 34% pools/glides which shows a large change from Pre-Resortation Year 4 (2015). No instream restoration occurred on this reach. The stream has underwent a lot of aggrading (Figure C-5). Many of the pools became more shallow due to the aggradation and some transitioned into riffles or runs altogether.

Cross-section 1 (Station 1+55) had been a Crossover Riffle when initially established during Pre-Restoration Year 1 of the study and again in Pre-Restoration Years 3 and 4. However, changes in channel profile resulted in the riffle feature migrating downstream, and this cross-section was within a pool feature when surveyed in Pre-Restoration Year 2 (Figure C-9). As a result, Year 2 bankfull cross-sectional dimensions changed significantly at this station, with the deepening of the channel bed (Table C-2). Pre-Restoration Year 4 streambed most closely resembled that of the Pre-Restoration Year 2 study. The right streambank had remained relatively unchanged at Cross-section 1 throughout the four year pre-restoration study while the left bank has slightly filled in between 2012 and 2015 (Figure C-15). Significant deepening also occurred at Cross-section 2 (Meander Bend at Station 2+07), and erosion of the outside (left) bank was also observed between Pre-Restoration Years 1 and 2 (Figure C-16). The left bank continued to erode between Pre-Restoration Years 2 and 3 while agraddation occurred in the stream bed near the left bank. Significant erosion continued and can be seem on the left bank between Pre-Restoration Years 3 and 4 as well as scouring of the left bank strembed. Consequently, bankfull cross-sectional dimensions and entrenchment ratios also differed significantly at this station between all four pre-restoration years (Table C-2).

In the first year of post restoration monitoring, Cross-Section 1 at Station 1+55 continued eroding slightly on the left bank while the right bank was aggading around the toe of the bank almost 0.5 feet (Figure C-15). Also, on the right bank there is a more defined bench developing and creating a new floodplain. Cross-Section 2 at Station 2+07 has underwent major changes since the last survey during Pre-Restoration Year 4 (2015). The left bank has eroded an additional 2 to 3 feet from 2015 and has undercut the bank (Figure C-16). The streambed at this cross-section has agradded on the right side of the channel due to the encroaching point bar.

Cross-section 1 (Crossover Riffle at Station 1+55), channel substrate became more fine, with the D_{50} decreasing from very coarse gravel to coarse gravel between Pre-Restoration Years 1 and 3 (Table C-3). During Pre-Restoration Year 4, D_{50} increased and was once again categorized in the very coarse gravel size class. The D_{84} decreased from small cobble to very coarse gravel and back to small cobble over the four years of pre-restoration. In Post-Restoration Year 1, the D50 went back down to coarse gravel and the D84 remained very coarse gravel. The D_{84} also decreased at Cross-section 2 (Meander Bend at Station 2+07) from small cobble in Pre-Restoration Year 1 to very coarse gravel in Pre-Restoration Years 2 and 3 to coarse gravel in Pre-Restoration Year 4. At Cross-section 2, D_{50} particle size classes remained the same between the first two years of pre-restoration study (medium gravel) and increased during the third (coarse gravel). During the fourth pre-restoration year, D_{50} size decreased from coarse gravel to fine gravel. In Post-Restoration Year 1, the D_{50} increased to medium gravel and the D84 increased to very coarse gravel. Reachwide, the D_{50} was coarse gravel during three of the four pre-restoration study years with a slight increase to very coarse gravel occurring in Year 3. The D_{84} showed the same pattern as the $D_{50,}$ increasing only during Pre-Restoration Year 3 to large cobble and remaining in the same small cobble class Pre-Restoration Years 1, 2, and 4. During the first post-restoration year (2017), the reachwide D_{50} was medium gravel and D_{84} was very coarse gravel both trending to smaller material than in years past.

4.4 WC04

No significant changes were observed in the profile of the downstream portion of the reach at site WC04 between the four years of pre-restoration study. However, during Pre-Restoration Years 2, 3, and 4 survey, the stream channel was dry from above the pool feature at Station 1+80 to the top of the reach at Station 3+00 and beyond. Around this same station and above, channel aggradation can be seen when comparing the profiles of the initial year and all the following years' surveys (Figure C-6) which may explain the decrease in water depth between these surveys. Reach length, slope, and proportion of features within the reach remained relatively unchanged (Table C-1).

The cross-sections within this reach also remained relatively unchanged between the first three years of pre-restoration study, with the exception of some lower bank erosion observed at Cross-section 1 (Meander at Station 1+08) between Pre-Restoration Years 1, 2, and 3 (Figures C-17). Furthermore, during Pre-Restoration Year 4, erosion on the lower left bank continued and is now more apparent resulting in higher bankfull and width depth dimensions. This station was identified as a riffle located just above the top of a pool during the initial year of pre-restoration monitoring, but was within part of the pool when surveyed in all other subsequent pre-restoration years. The channel was actively widening and cutting into the bank at this station during the Pre-Restoration Year 4 survey, resulting in changes in cross-sectional dimensions and this undercutting has continued to take place into the Post-Restoration Year 1 survey (Table C-2). The cross-sectional area increased slightly due to the increase in undercut bank but the overall top of bank area slightly decreased due to the growing point bar and bench (Figure C-17). Cross-section 1 at Station 1+56 is now in a meander run feature in Post-Restoration Year 1, a change from the original riffle feature in Pre-Restoration Year 1 and the pool feature in Pre-Restoration Years 1 through 4 (Table C-2). Cross-section 2 at Station 1+68 remains unchanged and stable, with slight aggradation occurring on the right side of the channel in Post-Restoration Year 1 (Figure C-18).

Reachwide D_{84} particle size classes remained the same during all four pre-restoration years (small cobble) but has seen a small decrease in Post-Restoration Year 1 to very coarse gravel (Table C-3). D_{84} remained the same at Cross-section 1 during the first three years of pre-restoration study (small cobble) and decreased during the fourth year to coarse gravel, where it remained in Post-Restoration Year 1. At Cross-section 2, D_{84} decreased from small cobble to very coarse gravel between Pre-Restoration Years 2 and 3 and increased back to small cobble between Pre-Restoration Years 3 and 4 and remains small cobble in Post-Restoration Year 1 (Table C-3). The D_{50} particle size class increased from coarse gravel to very coarse gravel between Pre-Restoration Years 2 and 3 and decreased back to coarse gravel during Pre-Restoration Year 4 for the reachwide survey. During the Post-Restoration Year 1 survey, the reachwide D_{50} slightly decreased to medium gravel (Table C-3). Cross-section 1 fluctuated by decreasing from medium gravel to very coarse sand and again increasing to medium gravel and Cross-section 2 remained the same (very coarse gravel) between Pre-Restoration Years 2, 3, and 4. In Post-Restoration Year 1, Cross-section 1's D_{50} remained medium gravel while Cross-section 2's D_{50} increased to coarse gravel (Table C-3).

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5.0 CONCLUSIONS

The data presented herein provide a first year assessment of conditions within the Wheel Creek watershed post-restoration efforts. During the sampling for the Pre-Restoration Years 1 and 2 study, none of the planned restoration projects had been completed within this watershed. During Pre-Restoration Year 3 study, however, two of at least seven planned restoration projects had been constructed, while the remaining projects were still in the planning stages. Continuted planning occurred during Pre-Restoration Year 4 but no new construction activites were initiated. As of the Post-Restoration Year 1 survey, all planned restoration projects were completed. Results of the geomorphic monitoring show that bank erosion continues to be prevalent in the two reaches (WC03, WC04) that did not receive stream restoration. Erosion of stream banks not only increases the sediment supply to the watershed but also provides a potential source of nutrients, especially phosphorus. Stream bank erosion is a common symptom of streams like those in Wheel Creek, where urban land cover is dominant (46.1%), contributing large amounts of impervious cover (21.4%) to the watershed (Becker, 2011). Although, efforts have been made to decrease the impact of damaging storm water flow causing erosion among the unstable banks. The two reaches that were restored (WC01, WC02) have vegetated stable banks in the first post-restoration survey, but are still somewhat entrenched with little access to a floodplain. It will be interesting to see how the stream adjusts to the newly designed channel in the coming years of post-restoration monitoring.

Additional geomorphic surveys will enable future comparisons to quantitatively evaluate changes in geomorphological conditions as a result of restoration efforts throughout the watershed. By comparing post-restoration conditions to the pre-restoration data, we can potentially quantify any benefits to the stream ecosystem resulting from restoration activities. With the current monitoring design, we may have the ability to assess the benefits of individual projects and assess the efficacy of individual restoration techniques. This would provide valuable data that may help guide the selection of restoration techniques in the future.

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6.0 REFERENCES

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APPENDIX A

PHOTOS

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WC01 – Facing upstream at Station 4+50

WC01 - Facing upstream at Station 3+00

WC01 – Facing upstream at Station 2+00

WC01 – Facing upstream at Station 1+00

WC01 – Facing upstream from Station 0+00

WC02 – Facing upstream at Station 3+00

WC02 – Facing upstream at Station 2+00

WC02 – Facing upstream at Station 1+00

WC02 – Facing upstream at Station 0+50

WC02 – Facing upstream at Station 0+00

WC03 – Facing downstream at Station 3+06

WC03 – Facing upstream at Station 2+50

WC03 – Facing upstream at Station 1+50

WC03 – Facing upstream at Station 0+50

WC03 – Facing upstream at station 0+00

WC04 – Facing downstream at Station 3+00

WC04 – Facing upstream at Station 2+00

WC04 – Facing upstream at Station 1+00

WC04 – Facing upstream at Station 0+50

WC04 – Facing upstream at Station 0+00

WC01 – XS-1 facing upstream

WC01 – XS-1 facing downstream

WC01 – XS-1 facing right bank

WC01 – XS-1 facing left bank

WC01 – XS-2 facing upstream

WC01 – XS-2 facing downstream

WC01 – XS-2 facing right bank

WC01 – XS-2 facing left bank

WC02 – XS-1 facing upstream

WC02 – XS-1 facing downstream

WC02 – XS-1 facing right bank

WC02 – XS-1 facing left bank

WC02 – XS-2 facing upstream

WC02 – XS-2 facing downstream

WC02 – XS-2 facing right bank

WC02 – XS-2 facing left bank

WC03 – XS-1 facing upstream

WC03 – XS-1 facing downstream

WC03 – XS-1 facing right bank

WC03 – XS-1 facing left bank

WC03 – XS-2 facing upstream

WC03 – XS-2 facing downstream

WC03 – XS-2 facing right bank

WC03 – XS-2 facing left bank

WC04 – XS-1 facing upstream

WC04 – XS-1 facing downstream

WC04 – XS-1 facing right bank

WC04 – XS-1 facing left bank

WC04 – XS-2 facing upstream

WC04 – XS-2 facing downstream

WC04– XS-2 facing right bank

WC04 – XS-2 facing left bank

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APPENDIX B

GEOMORPHIC ASSESSMENT DATA

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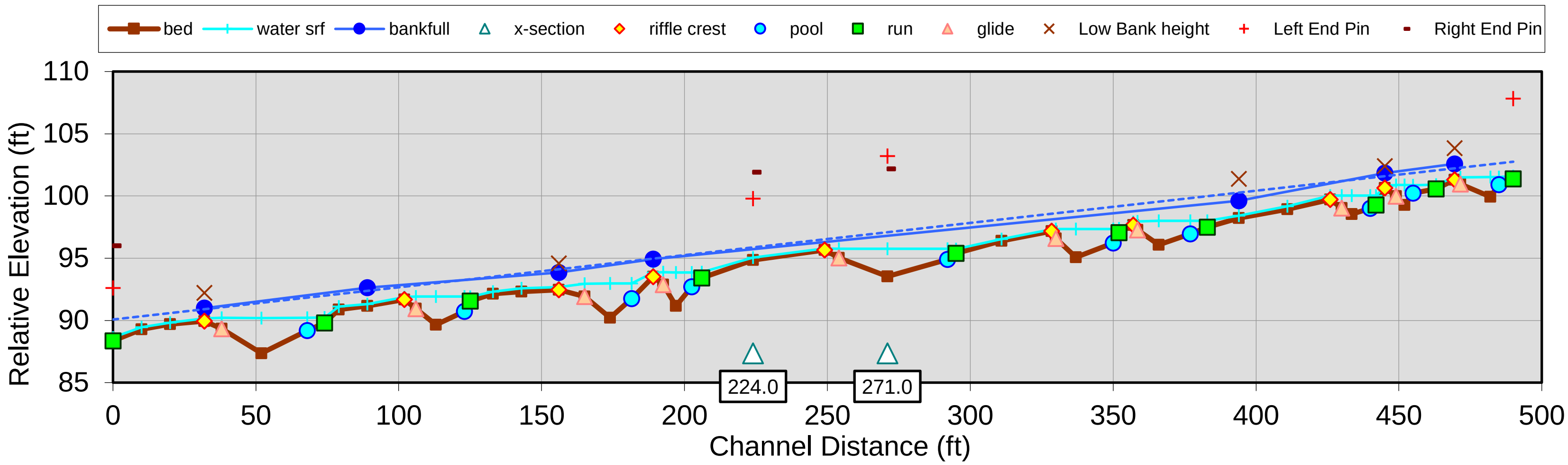
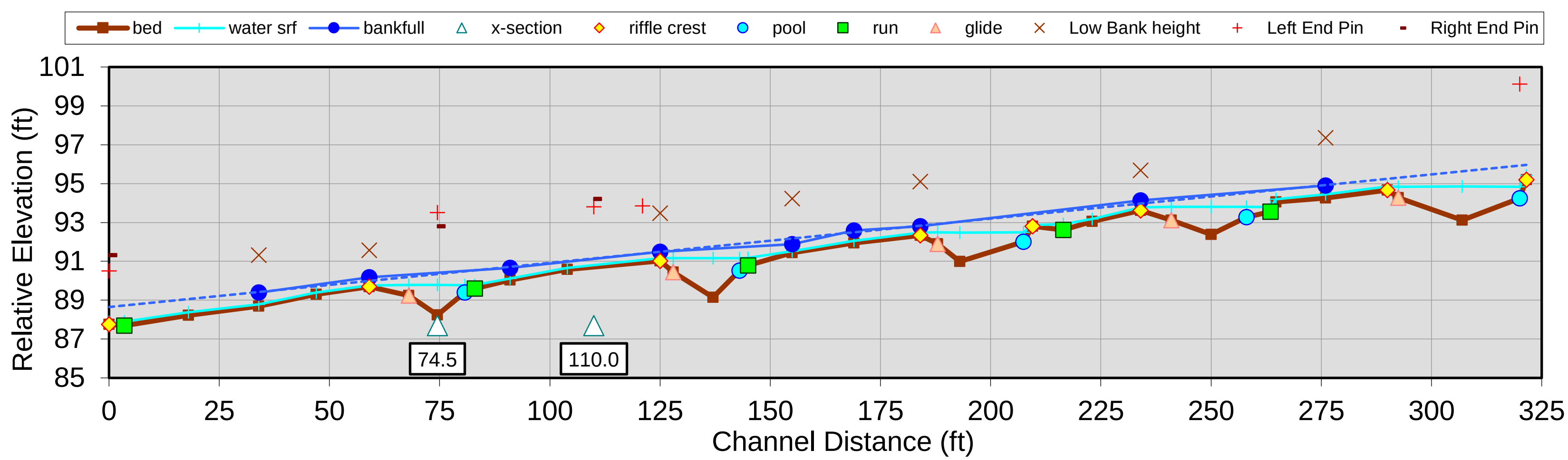
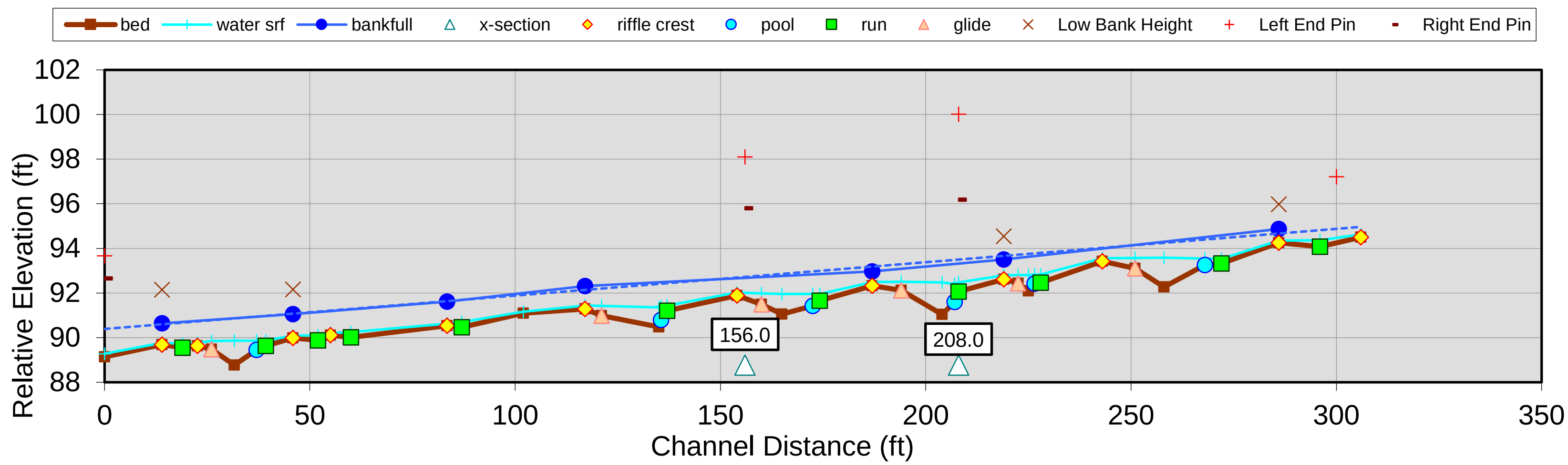
Wheel Creek WC-01 2017



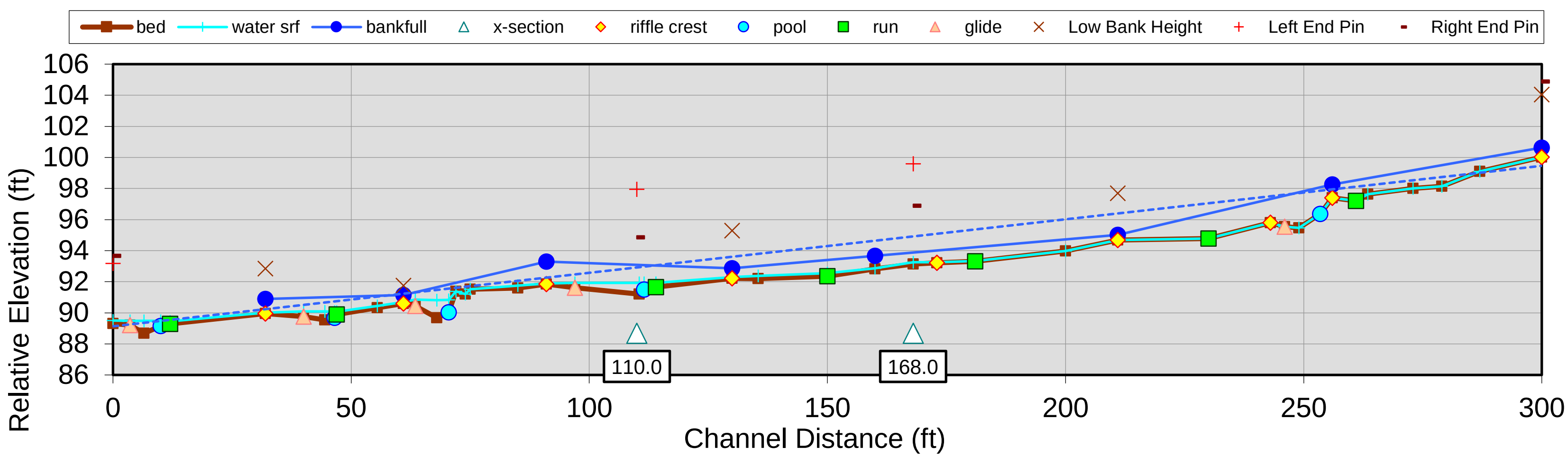
Wheel Creek WC-02 2017

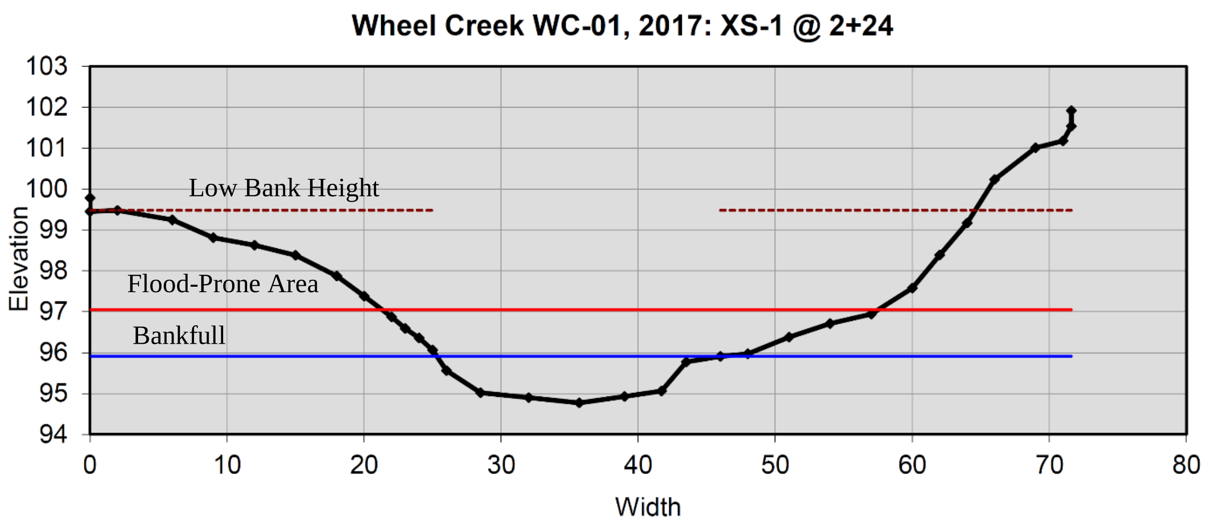


Wheel Creek WC-03 2017

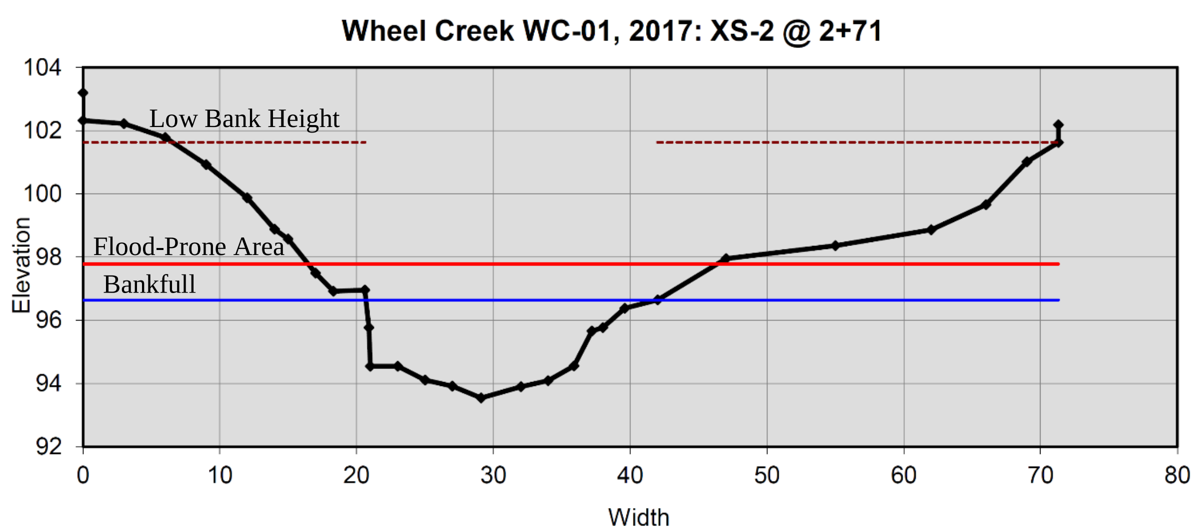


Wheel Creek WC-04 2017

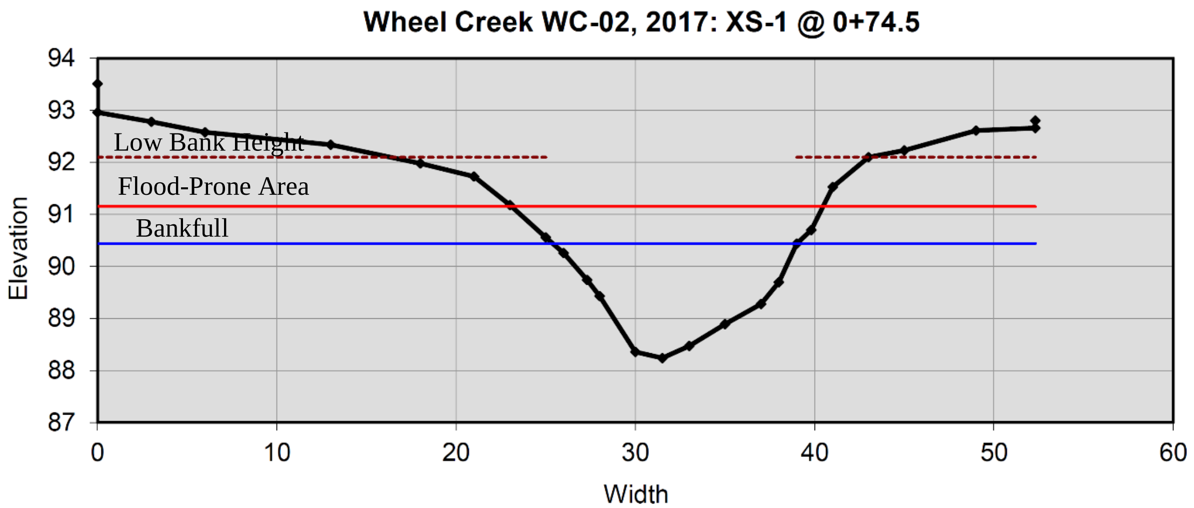




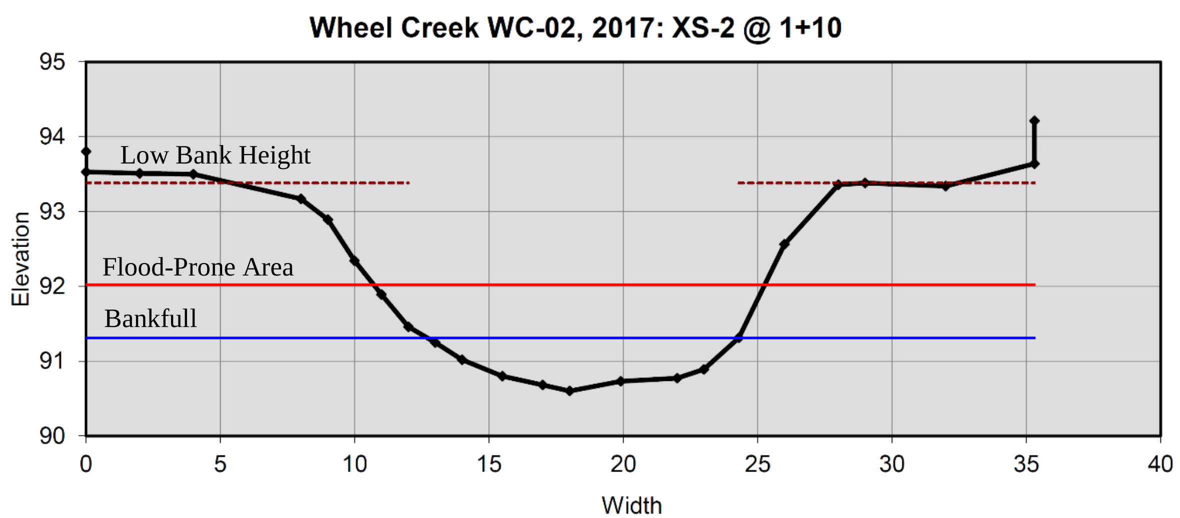
Bankfull Dimensions		Flood Dimensions		Materials	
16.0	x-section area (ft.sq.)	36.2	W flood prone area (ft)	52	D50 Riffle (mm)
20.7	width (ft)	1.7	entrenchment ratio	120	D84 Riffle (mm)
0.8	mean depth (ft)	4.7	low bank height (ft)		
1.1	max depth (ft)	4.1	low bank height ratio		
21.0	wetted parimeter (ft)				
0.8	hyd radi (ft)				
26.8	width-depth ratio				



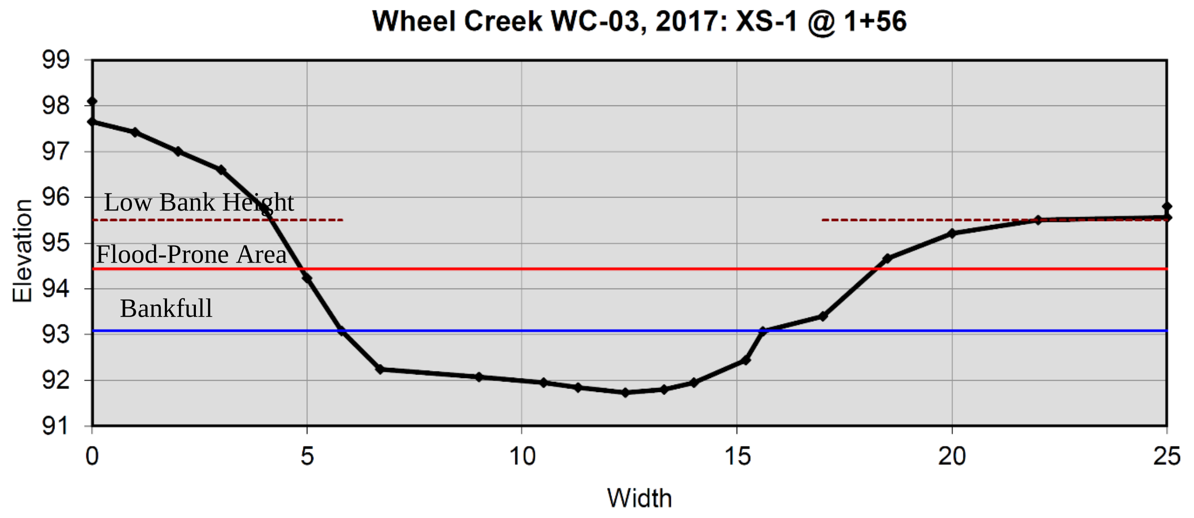
Bankfull Dimensions		Flood Dimensions		Materials	
42.6	x-section area (ft.sq.)	29.9	W flood prone area (ft)	11	D50 Riffle (mm)
21.3	width (ft)	1.4	entrenchment ratio	57	D84 Riffle (mm)
2.0	mean depth (ft)	8.1	low bank height (ft)		
3.1	max depth (ft)	2.6	low bank height ratio		
23.8	wetted parimeter (ft)				
1.8	hyd radi (ft)				
10.7	width-depth ratio				



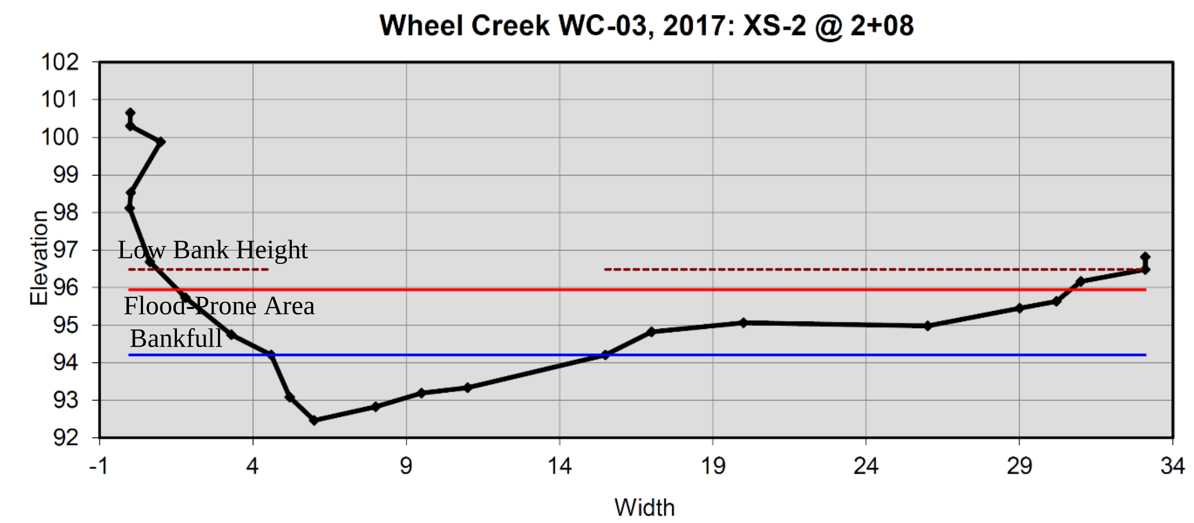
Bankfull Dimensions		Flood Dimensions		Materials	
18.2	x-section area (ft.sq.)	17.4	W flood prone area (ft)	26	D50 Riffle (mm)
13.6	width (ft)	1.3	entrenchment ratio	85	D84 Riffle (mm)
1.3	mean depth (ft)	3.9	low bank height (ft)		
2.2	max depth (ft)	1.8	low bank height ratio		
14.5	wetted parimeter (ft)				
1.3	hyd radi (ft)				
10.2	width-depth ratio				



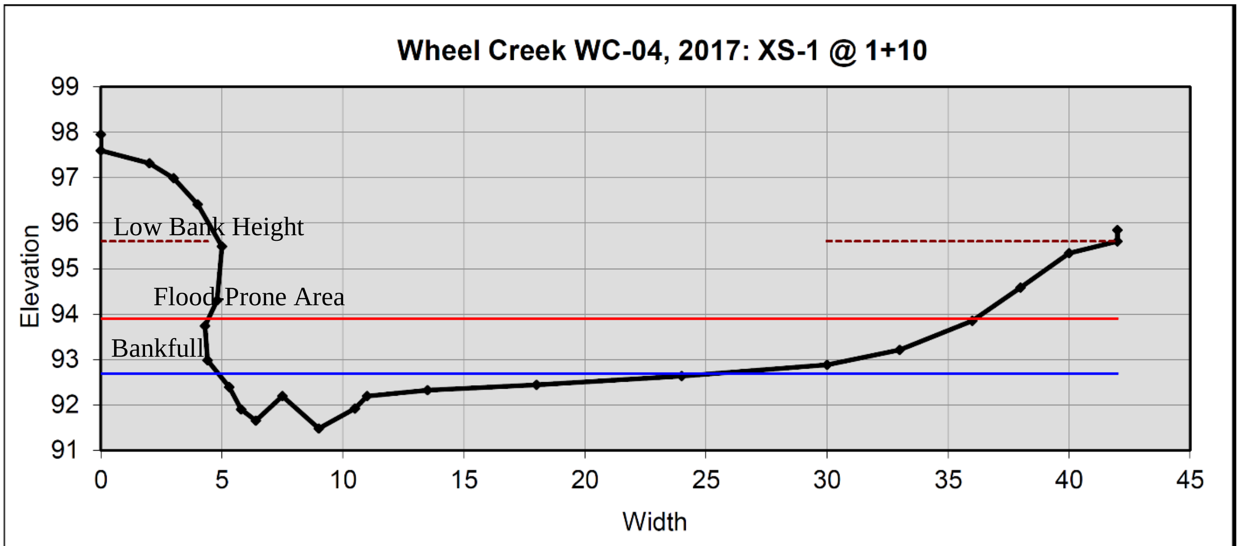
Bankfull Dimensions		Flood Dimensions		Materials	
5.5	x-section area (ft.sq.)	14.6	W flood prone area (ft)	4.3	D50 Riffle (mm)
11.6	width (ft)	1.3	entrenchment ratio	19	D84 Riffle (mm)
0.5	mean depth (ft)	2.8	low bank height (ft)		
0.7	max depth (ft)	3.9	low bank height ratio		
11.7	wetted parimeter (ft)				
0.5	hyd radi (ft)				
24.6	width-depth ratio				



Bankfull Dimensions		Flood Dimensions		Materials	
7.3	x-section area (ft.sq.)	13.4	W flood prone area (ft)	26	D50 Riffle (mm)
7.9	width (ft)	1.7	entrenchment ratio	59	D84 Riffle (mm)
0.9	mean depth (ft)	3.8	low bank height (ft)		
1.4	max depth (ft)	2.8	low bank height ratio		
8.7	wetted parimeter (ft)				
0.8	hyd radi (ft)				
8.6	width-depth ratio				



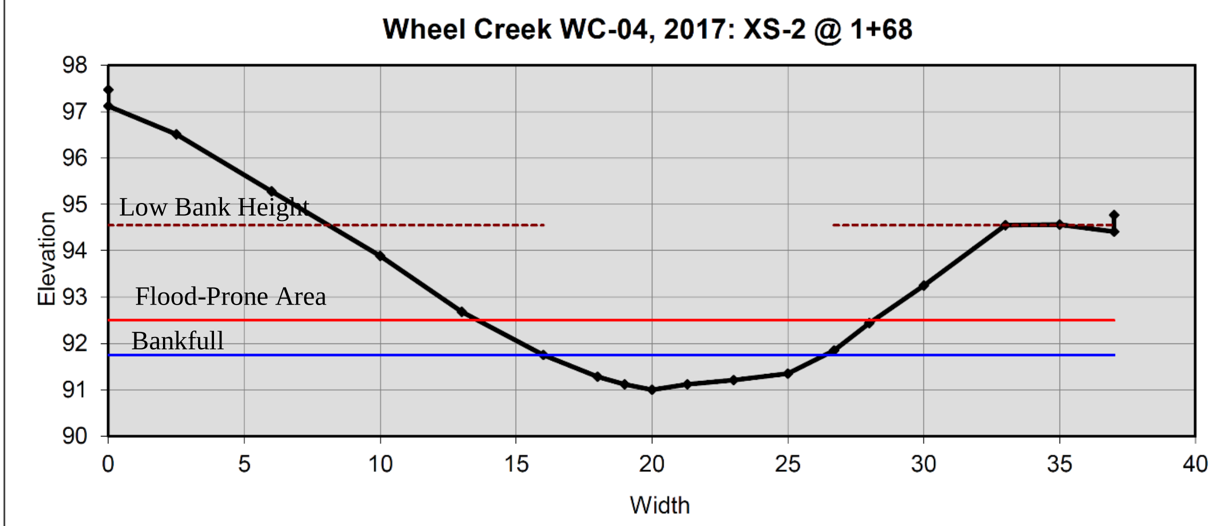
Bankfull Dimensions		Flood Dimensions		Materials	
9.8	x-section area (ft.sq.)	29.1	W flood prone area (ft)	17	D50 Riffle (mm)
10.9	width (ft)	2.7	entrenchment ratio	61	D84 Riffle (mm)
0.9	mean depth (ft)	4.0	low bank height (ft)		
1.7	max depth (ft)	2.3	low bank height ratio		
11.9	wetted parimeter (ft)				
0.8	hyd radi (ft)				
12.2	width-depth ratio				



Bankfull Dimensions	
8.3	x-section area (ft.sq.)
20.6	width (ft)
0.4	mean depth (ft)
1.2	max depth (ft)
21.4	wetted parimeter (ft)
0.4	hyd radi (ft)
51.3	width-depth ratio

Flood Dimensions	
31.7	W flood prone area (ft)
1.5	entrenchment ratio
4.1	low bank height (ft)
3.4	low bank height ratio

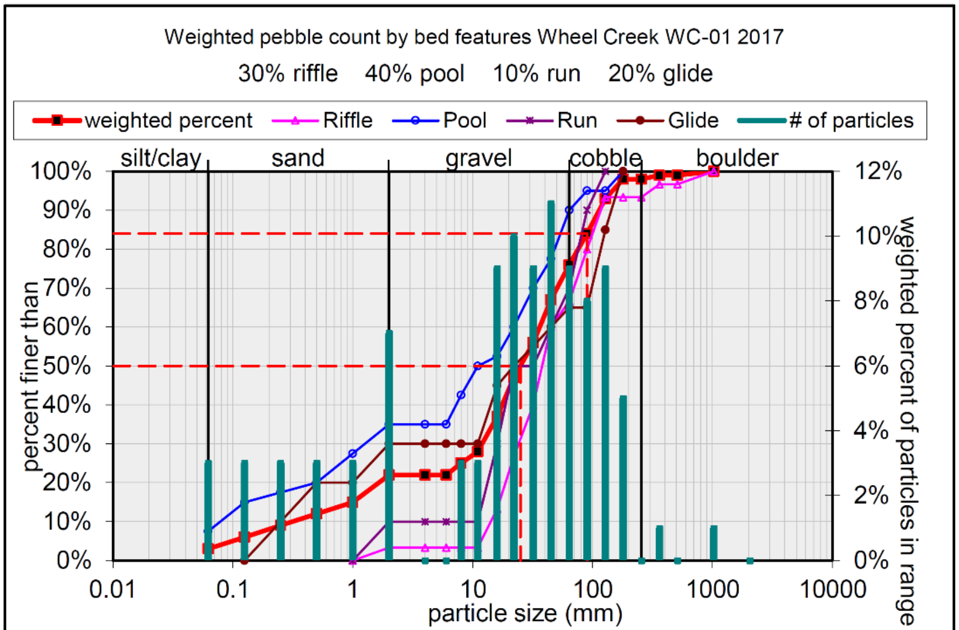
Materials	
12	D50 Riffle (mm)
26	D84 Riffle (mm)



Bankfull Dimensions	
4.8	x-section area (ft.sq.)
10.4	width (ft)
0.5	mean depth (ft)
0.8	max depth (ft)
10.5	wetted parimeter (ft)
0.5	hyd radi (ft)
22.3	width-depth ratio

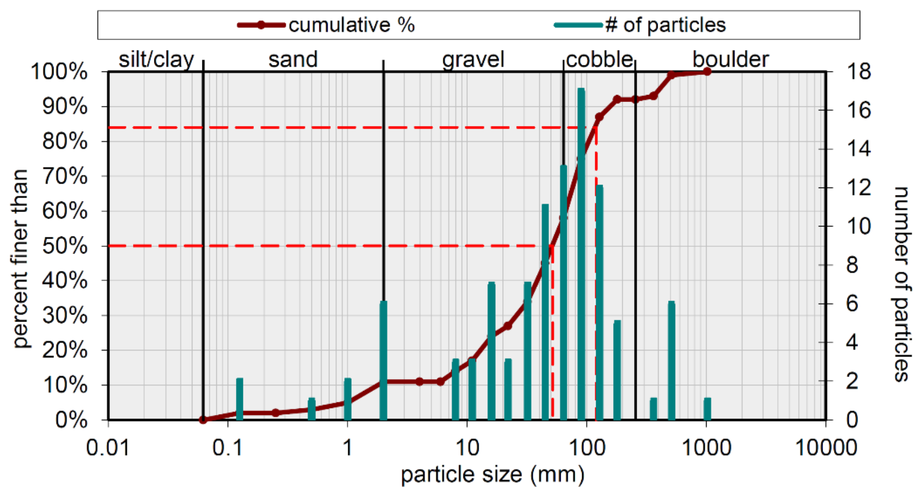
Flood Dimensions	
14.6	W flood prone area (ft)
1.4	entrenchment ratio
3.6	low bank height (ft)
4.7	low bank height ratio

Materials	
43	D50 Riffle (mm)
99	D84 Riffle (mm)



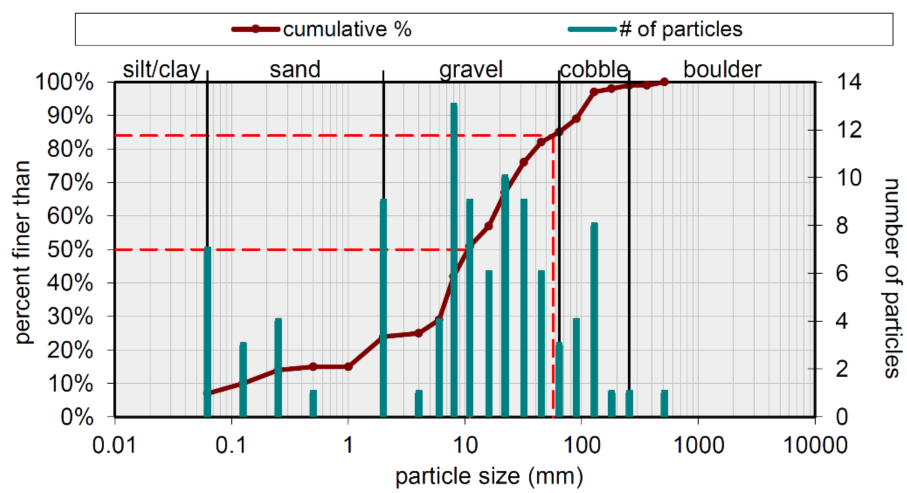
Size (mm)			Size Distribution			Type	
D16	1.1		mean	9.9		silt/clay	3%
D35	15		dispersion	13.2		sand	19%
D50	25		skewness	-0.29		gravel	54%
D65	42					cobble	22%
D84	90					boulder	2%
D95	150						

Riffle Surface Pebble Count, Wheel Creek: WC-01 2017: XS-1 @ 2+24

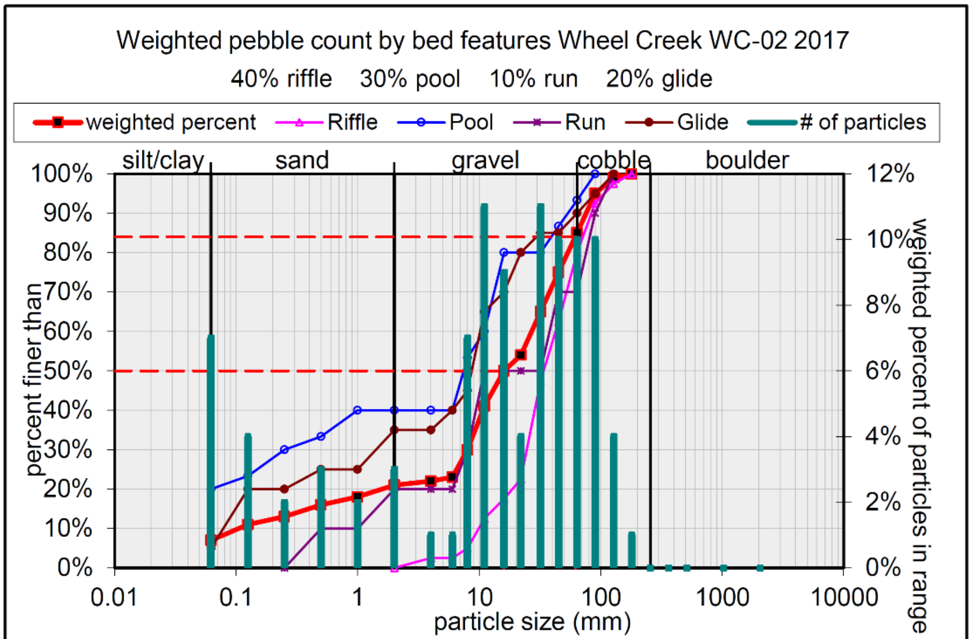


Size (mm)		Size Distribution		Type	
D16	9.9	mean	34.5	silt/clay	0%
D35	33	dispersion	3.8	sand	11%
D50	52	skewness	-0.17	gravel	47%
D65	74			cobble	34%
D84	120			boulder	8%
D95	410				

Meander Bend Pebble Count, Wheel Creek WC-01 2017: XS-2 @ 2+71

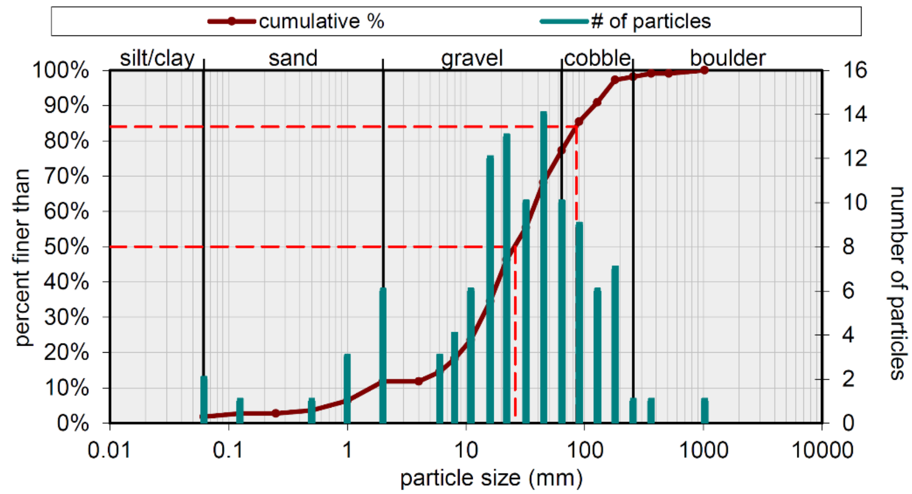


Size (mm)			Size Distribution		Type	
D16	1.1	3.4	mean	7.9	silt/clay	7%
D35	6.9	12	dispersion	7.6	sand	17%
D50	11	17	skewness	-0.11	gravel	61%
D65	21	20			cobble	14%
D84	57	29			boulder	1%
D95	120	39				



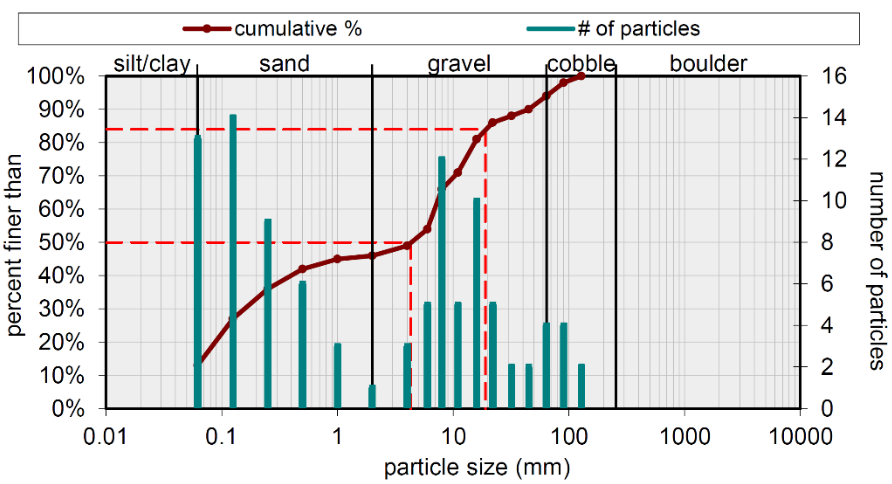
Size (mm)			Size Distribution			Type	
D16	0.5		mean	5.6		silt/clay	7%
D35	9.2		dispersion	17.9		sand	14%
D50	16		skewness	-0.32		gravel	64%
D65	32					cobble	15%
D84	62					boulder	0%
D95	90						

Riffle Surface Pebble Count, Wheel Creek: WC-02 2017: XS-1 @ 0+74.5

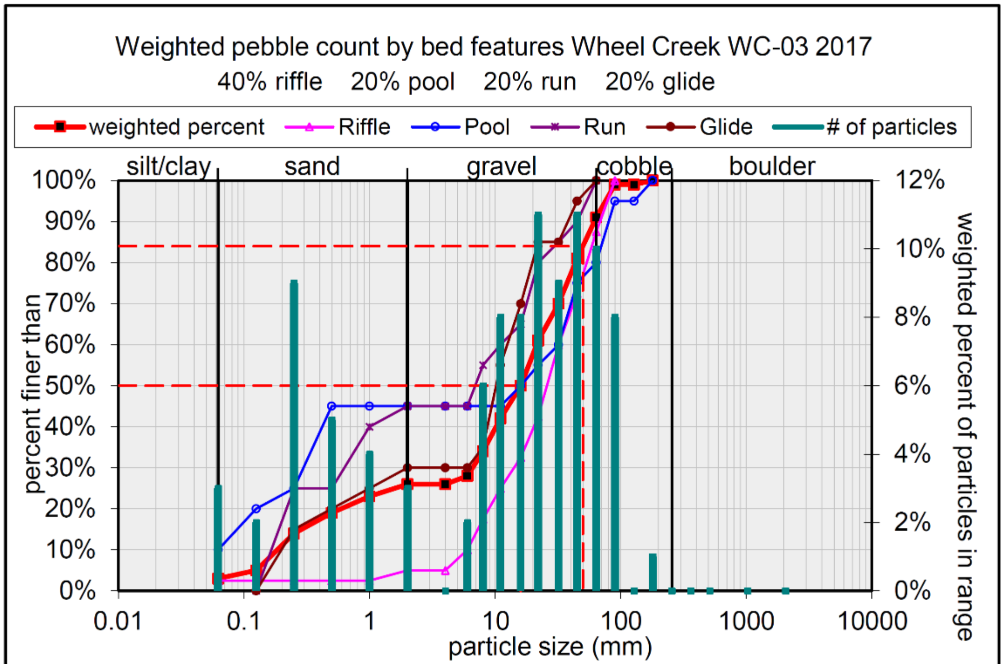


Size (mm)		Size Distribution		Type	
D16	6.7	mean	23.9	silt/clay	2%
D35	16	dispersion	3.6	sand	10%
D50	26	skewness	-0.04	gravel	65%
D65	41			cobble	21%
D84	85			boulder	2%
D95	160				

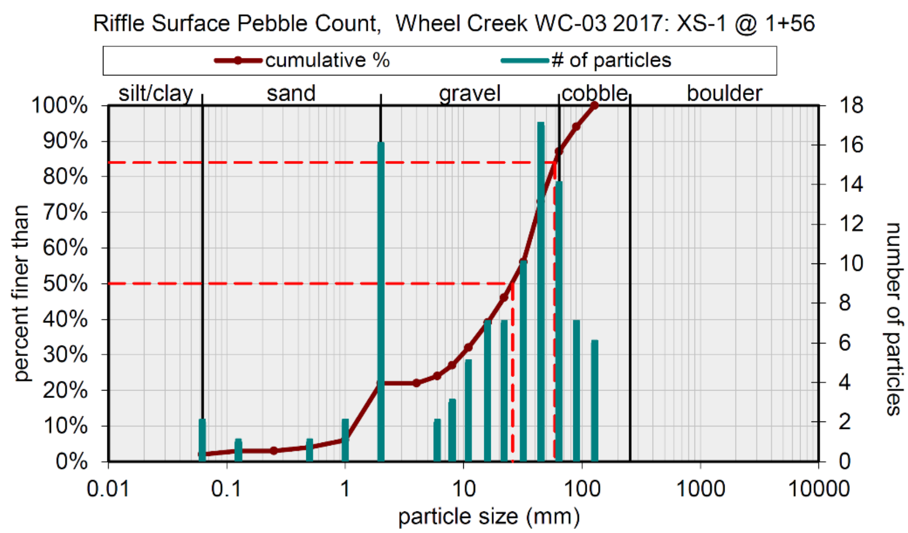
Meander Bend/Pool Pebble Count, Wheel Creek WC-02 2017: XS-2 @ 1+10



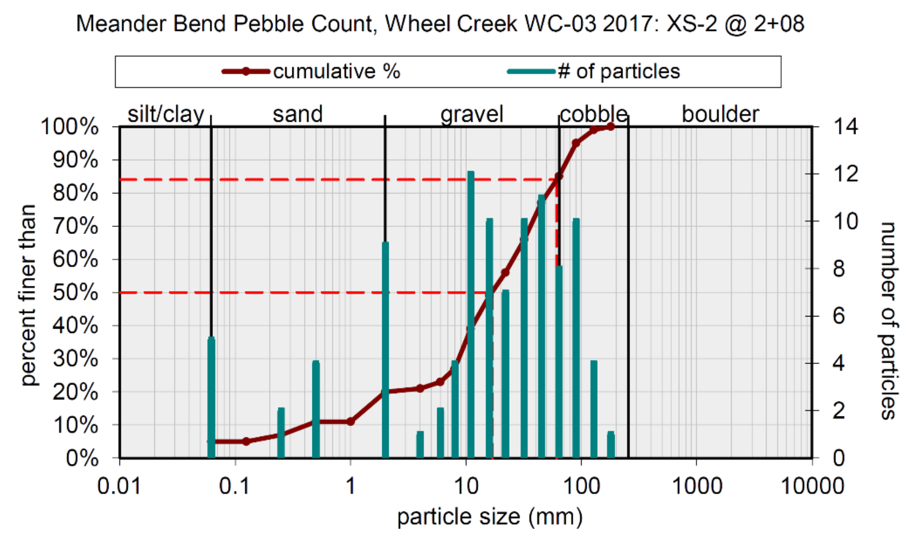
Size (mm)			Size Distribution		Type	
D16	0.072	3.4	mean	1.2	silt/clay	13%
D35	0.23	12	dispersion	32.1	sand	33%
D50	4.3	17	skewness	-0.36	gravel	48%
D65	7.8	20			cobble	6%
D84	19	29			boulder	0%
D95	70	39				



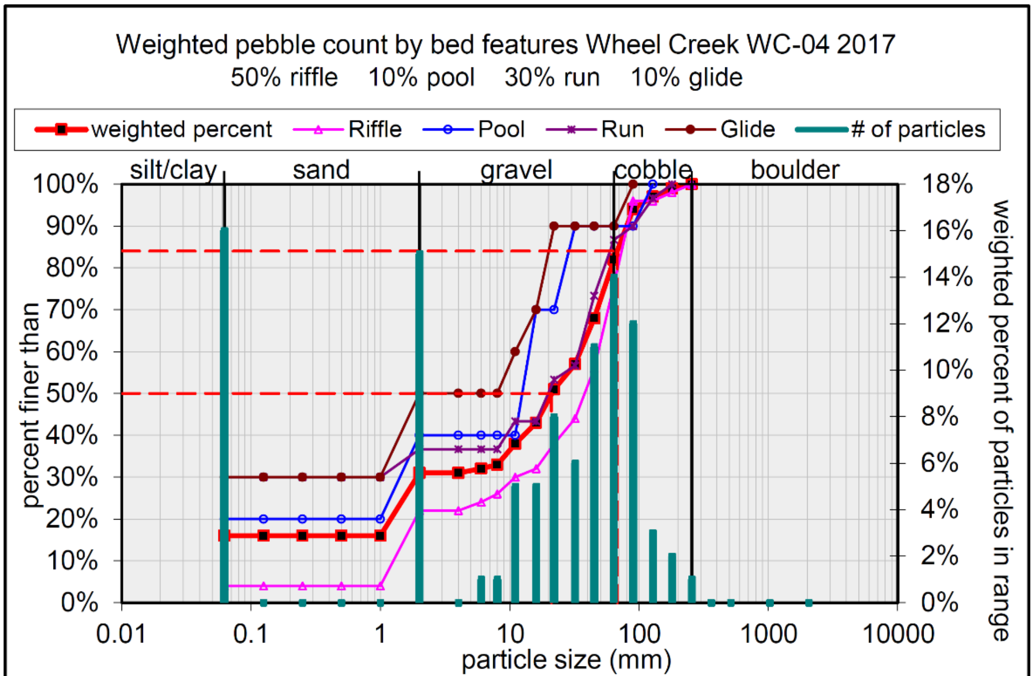
Size (mm)		Size Distribution		Type	
D16	0.33	mean	4.1	silt/clay	3%
D35	8.3	dispersion	25.8	sand	23%
D50	16	skewness	-0.40	gravel	65%
D65	26			cobble	9%
D84	50			boulder	0%
D95	76				



Size (mm)		Size Distribution		Type	
D16	1.5	mean	9.4	silt/clay	2%
D35	13	dispersion	9.8	sand	20%
D50	26	skewness	-0.35	gravel	65%
D65	38			cobble	13%
D84	59			boulder	0%
D95	95				



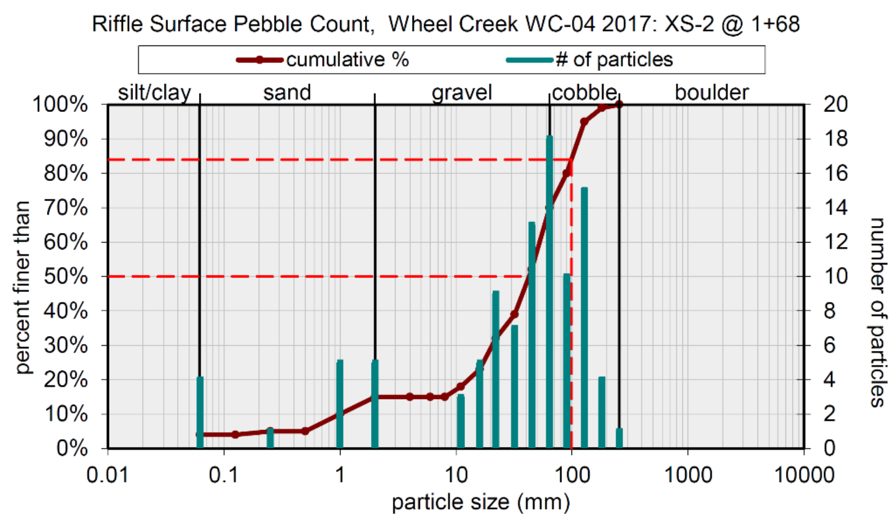
Size (mm)			Size Distribution		Type	
D16	1.5	3.4	mean	9.6	silt/clay	5%
D35	9.9	12	dispersion	7.5	sand	15%
D50	17	17	skewness	-0.20	gravel	65%
D65	31	20			cobble	15%
D84	61	29			boulder	0%
D95	90	39				



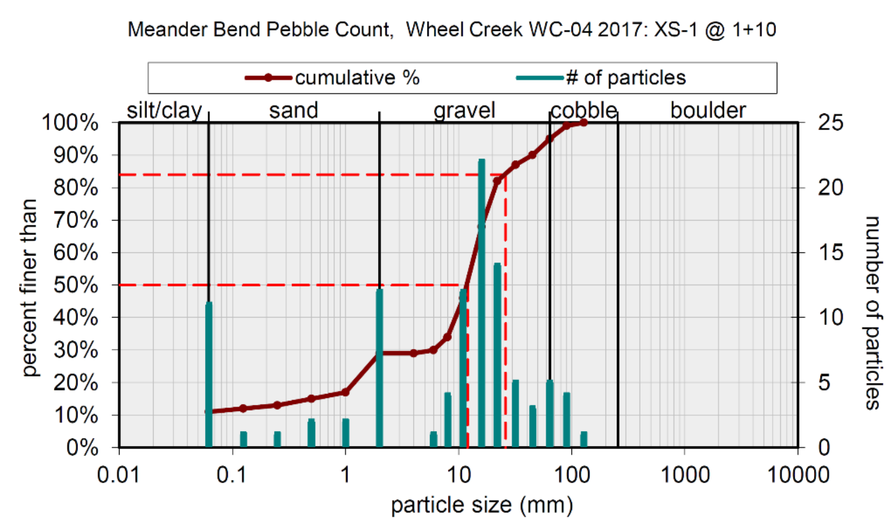
Size (mm)	
D16	0.062
D35	9.1
D50	21
D65	41
D84	68
D95	100

Size Distribution	
mean	2.1
dispersion	171.0
skewness	-0.58

Type	
silt/clay	16%
sand	15%
gravel	51%
cobble	18%
boulder	0%



Size (mm)		Size Distribution		Type	
D16	8.9	mean	29.7	silt/clay	4%
D35	26	dispersion	3.6	sand	11%
D50	43	skewness	-0.16	gravel	55%
D65	58			cobble	30%
D84	99			boulder	0%
D95	130				



Size (mm)			Size Distribution		Type	
D16	0.71	3.4	mean	4.3	silt/clay	11%
D35	8.2	12	dispersion	9.5	sand	18%
D50	12	17	skewness	-0.36	gravel	66%
D65	15	20			cobble	5%
D84	26	29			boulder	0%
D95	64	39				

APPENDIX C

ANNUAL COMPARISONS

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Table C-1. Comparisons of Longitudinal Profile Survey Pre-Restoration Year 1 – Year 4 (2010-2015) and Post-Restoration Year 1 (2017)

Reach	Year	Length (ft)	Slope	Proportion of Features			
				Riffle	Run	Pool	Glide
WC01	2010	400	2.3%	43.6%	11.3%	22.1%	23.0%
	2012	420	2.2%	54.6%	7.3%	29.2%	8.9%
	2013	420	2.2%	55.7%	8.2%	23.8%	12.3%
	2015	420	2.2%	50.9%	24.8%	14.1%	10.2%
	2017	*490*	*2.6%*	*47.5%*	*7.6%*	*36.6%*	*8.3%*
WC02	2010	350	2.3%	53.4%	0%	46.6%	0%
	2012	350	2.4%	33.7%	11.0%	38.6%	16.7%
	2013	350	2.3%	48.1%	12.6%	26.3%	13.0%
	2015	350	2.2%	49.4%	25.1%	13.4%	12.1%
	2017	*321.5*	*2.3%*	*57.3%*	*6.3%*	*28.5%*	*10.5%*
WC03	2010	300	1.7%	34.4%	0%	65.6%	0%
	2012	300	1.8%	24.0%	8.5%	54.9%	12.6%
	2013	306.3	1.6%	37.2%	15.9%	30.4%	16.5%
	2015	306	1.7%	32.0%	9.5%	34.0%	24.5%
	2017	*306*	*1.7%*	*52.4%*	*13.6%*	*23.5%*	*10.5%*
WC04	2010	300	3.5%	60.0%	0%	40.0%	0%
	2012	300	3.4%	41.3%	16.2%	30.3%	12.2%
	2013	300	3.4%	46.5%	11.0%	27.9%	14.6%
	2015	300	3.4%	50.3%	21.7%	19.0%	9.0%
	2017	*300*	*3.5%*	*48.2%*	*24.3%*	*14.0%*	*13.5%*

*Profile's and XS's re-established during Post-Restoration Year 1 (2017)

Table C-2. Comparisons of Cross-sectional Survey Analyses Year 1 – Year 4

Reach	Year	Station	Feature	Bankfull Width (ft)	Mean Depth (ft)	Width/ Depth Ratio	Entrench-ment Ratio	Bankfull Area (ft^2)	Top of Bank Area (ft^2)
WC01*	2010	2+30	Crossover Riffle	21.1	1.0	22.2	1.5	20.1	73.0
	2012	2+30	Crossover Riffle	21.3	1.1	18.6	1.5	24.5	78.1
	2013	2+29	Crossover Riffle	21.6	1.1	20.2	1.5	23.2	66.9
	2015	2+29	Crossover Riffle	21.0	1.0	21.6	1.5	20.5	74.8
	2017	*2+24*	*Crossover Riffle*	*20.7*	*0.8*	*26.8*	*1.7*	*16.0*	*164.4*
	2010	2+95	Meander/Riffle	22.1	0.8	26.0	1.5	18.8	230.1
	2012	2+95	Meander/Riffle	28.9	0.8	37.5	1.5	22.3	246.9
	2013	2+95	Meander/Riffle	29.0	0.9	34.1	1.5	24.7	212.7
	2015	2+95	Meander/Riffle	29.1	1.2	25.0	1.6	33.8	259.6
	2017	*2+71*	*Meander/Pool*	*21.3*	*2.0*	*10.7*	*1.4*	*42.6*	*269.7*
WC02*	2010	1+37	Crossover Riffle	13.1	0.7	18.4	1.2	9.3	31.6
	2012	1+38	Crossover Riffle	14.3	0.6	24.1	1.2	8.5	37.1
	2013	1+38	Crossover Riffle	14.3	0.7	19.4	1.2	10.6	36.7
	2015	1+38	Crossover Riffle	13.9	0.8	17.9	1.2	10.8	28.4
	2017	*1+10*	*Crossover Riffle*	*11.6*	*0.5*	*24.6*	*1.3*	*5.5*	*38.6*
	2010	3+24	Meander/Riffle	16.7	0.9	19.3	1.3	14.5	70.3
	2012	3+24	Meander/Riffle	14.6	0.6	23.8	1.4	9.0	71.7
	2013	3+25.5	Meander/Riffle	15.6	0.7	21.8	1.5	11.1	72.0
	2015	3+24	Meander/Riffle	16.4	0.9	19.1	1.4	14.0	74.6
	2017	*0+74.5*	*Pool*	*13.6*	*1.3*	*10.2*	*1.3*	*18.2*	*49.0*
WC03	2010	1+55	Crossover Riffle	9.2	0.4	24.1	1.1	3.5	37.5
	2012	1+57	Pool	10.6	1.1	9.8	1.3	11.4	41.3
	2013	1+56	Crossover Riffle	10.1	0.9	11.8	1.2	8.6	38.2
	2015	1+55	Crossover Riffle	9.3	0.7	12.7	1.2	6.8	37.9
	2017	*1+56*	*Crossover Riffle*	*7.3*	*0.9*	*8.6*	*1.7*	*7.3*	*35*
	2010	2+07	Meander/Pool	7.2	0.5	13.0	1.9	3.9	43.8
	2012	2+08	Meander/Pool	10.2	1.2	8.4	2.5	12.5	56.2
	2013	2+12	Meander/Pool	9.7	1.0	10.0	2.7	9.4	55.0
	2015	2+07	Meander/Pool	9.9	1.1	9.4	2.8	10.5	61.4
	2017	*2+08*	*Meander/Run*	*9.8*	*0.9*	*12.2*	*2.7*	*9.8*	*61.5*
WC04	2010	1+08	Meander/Riffle	4.3	0.4	9.8	4.3	1.9	92.5
	2012	1+08	Meander/Pool	6.7	0.6	11.4	3.9	4.0	95.9
	2013	1+08	Meander/Pool	13	0.6	23.5	2.2	7.2	99.9
	2015	1+08	Meander/Pool	13.6	0.6	24.0	2.3	7.7	102.8
	2017	*1+10*	*Meander/Pool*	*20.6*	*0.4*	*51.3*	*1.5*	*8.3*	*99.8*
	2010	1+68	Crossover Riffle	8.9	0.4	24.0	1.4	3.3	55.9
	2012	1+68	Crossover Riffle	9.2	0.5	18.9	1.5	4.4	57.8
	2013	1+68	Crossover Riffle	10.4	0.5	20.4	1.4	5.3	56.3
	2015	1+68	Crossover Riffle	11.1	0.6	17.4	1.6	7.1	55.6
	2017	*1+68*	*Crossover Riffle*	*10.4*	*0.5*	*22.3*	*1.4*	*4.8*	*54.8*

*Profile's and XS's re-established during Post-Restoration Year 1 (2017)

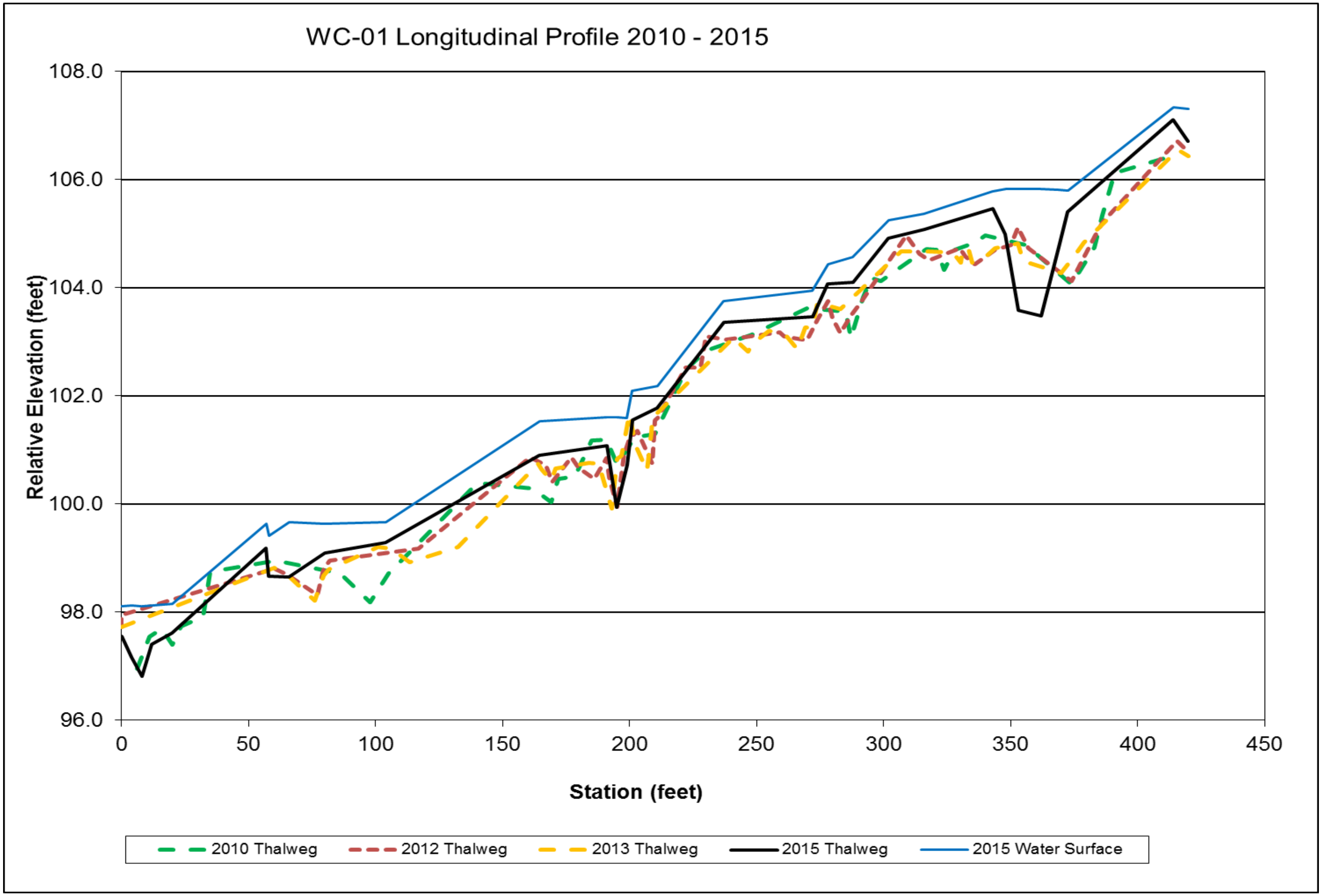

Figure C-1. WC-01 Chart (Pre-Restoration)

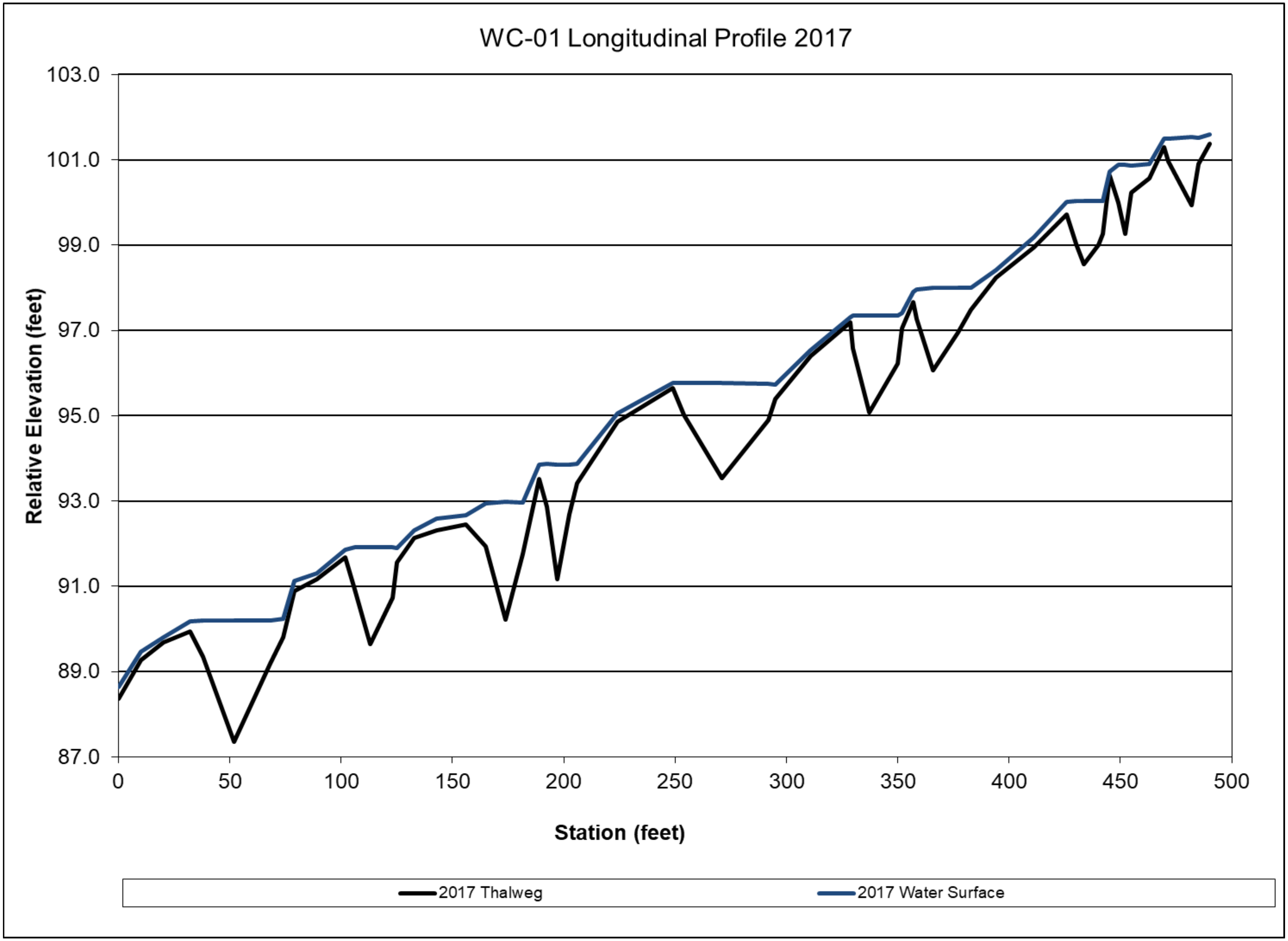
WC-01 Longitudinal Profile 2017
103.0
101.0
99.0
97.0
95.0
93.0
91.0
89.0
87.0
Relative Elevation (feet)
0
50
100
150
200
250
300
350
400
450
500
Station (feet)
2017 Thalweg
2017 Water Surface

Figure C-2. WC-01 Chart (Post-Restoration)

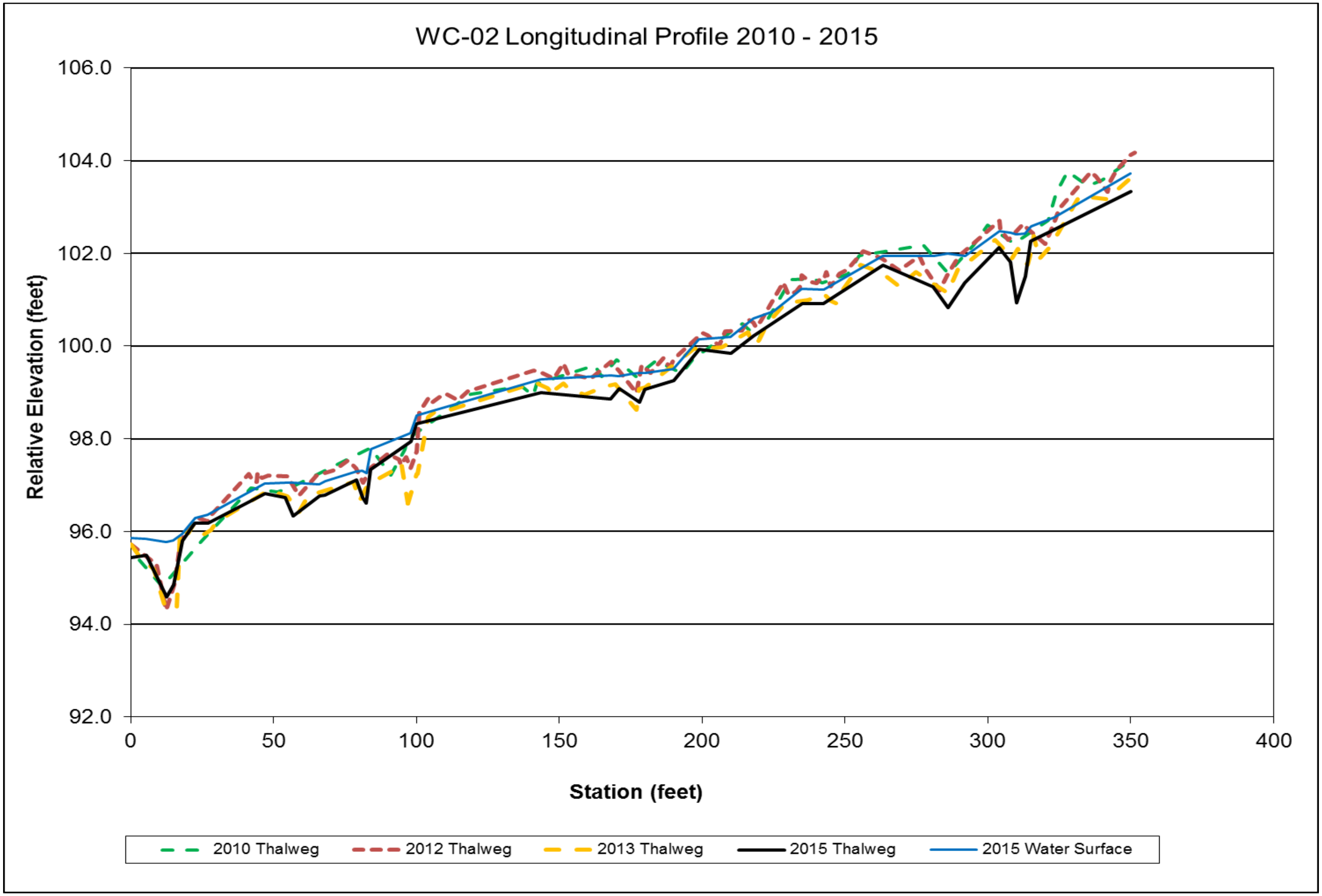

Figure C-3. WC-02 Chart (Pre-Restoration)

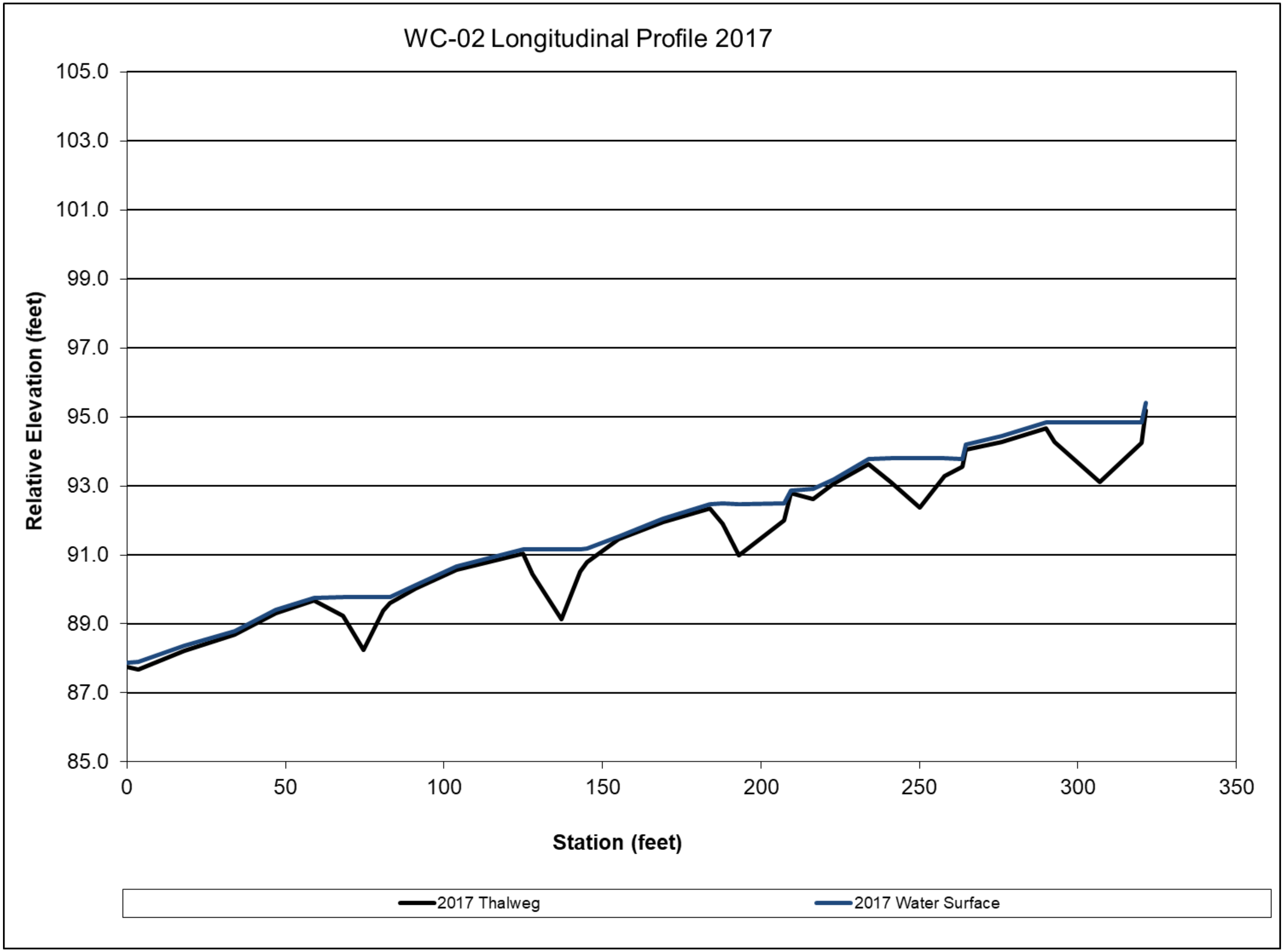

Figure C-4. WC-02 Chart (Post-Restoration)

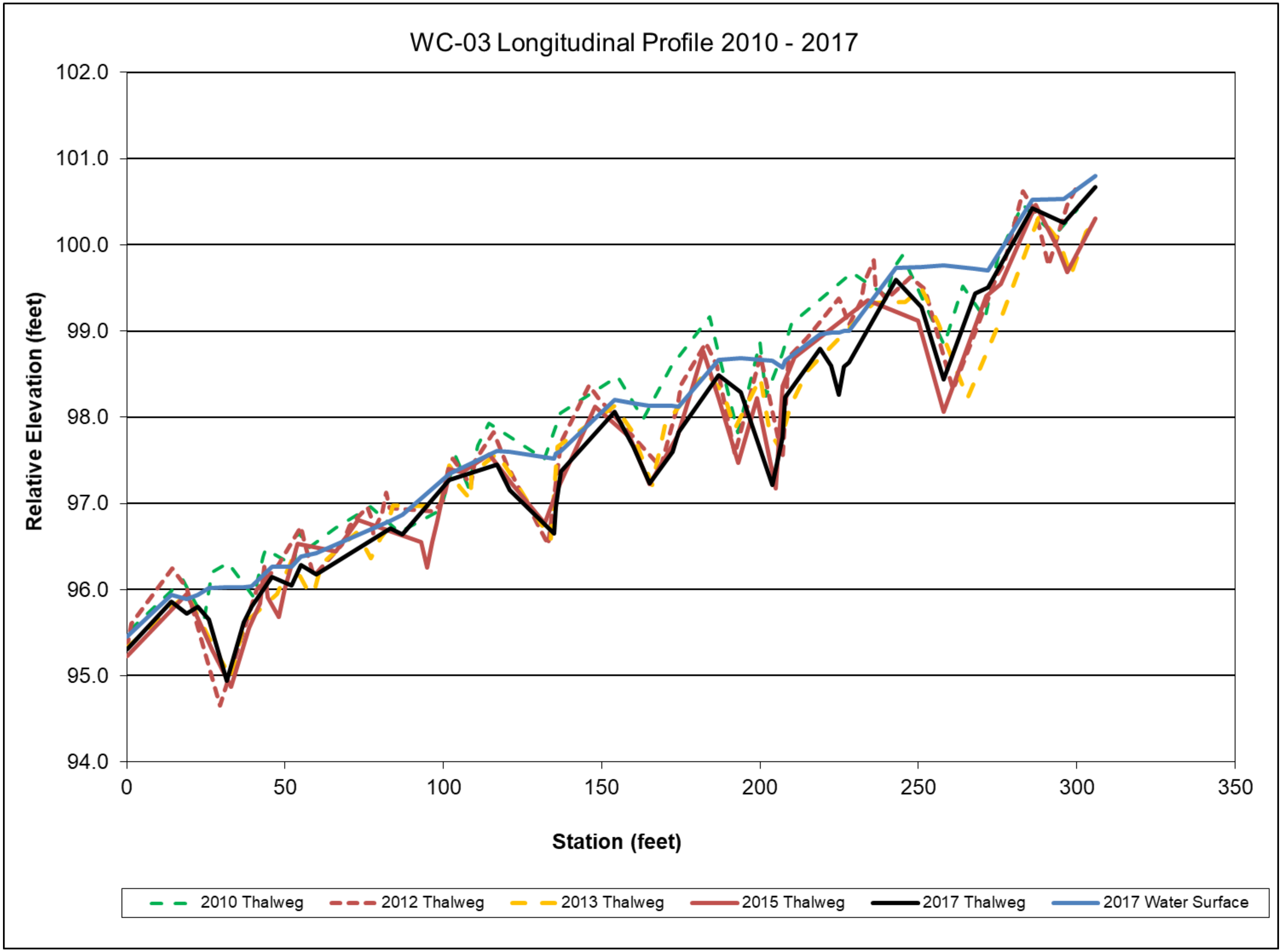

Figure C-5. WC-03 Chart

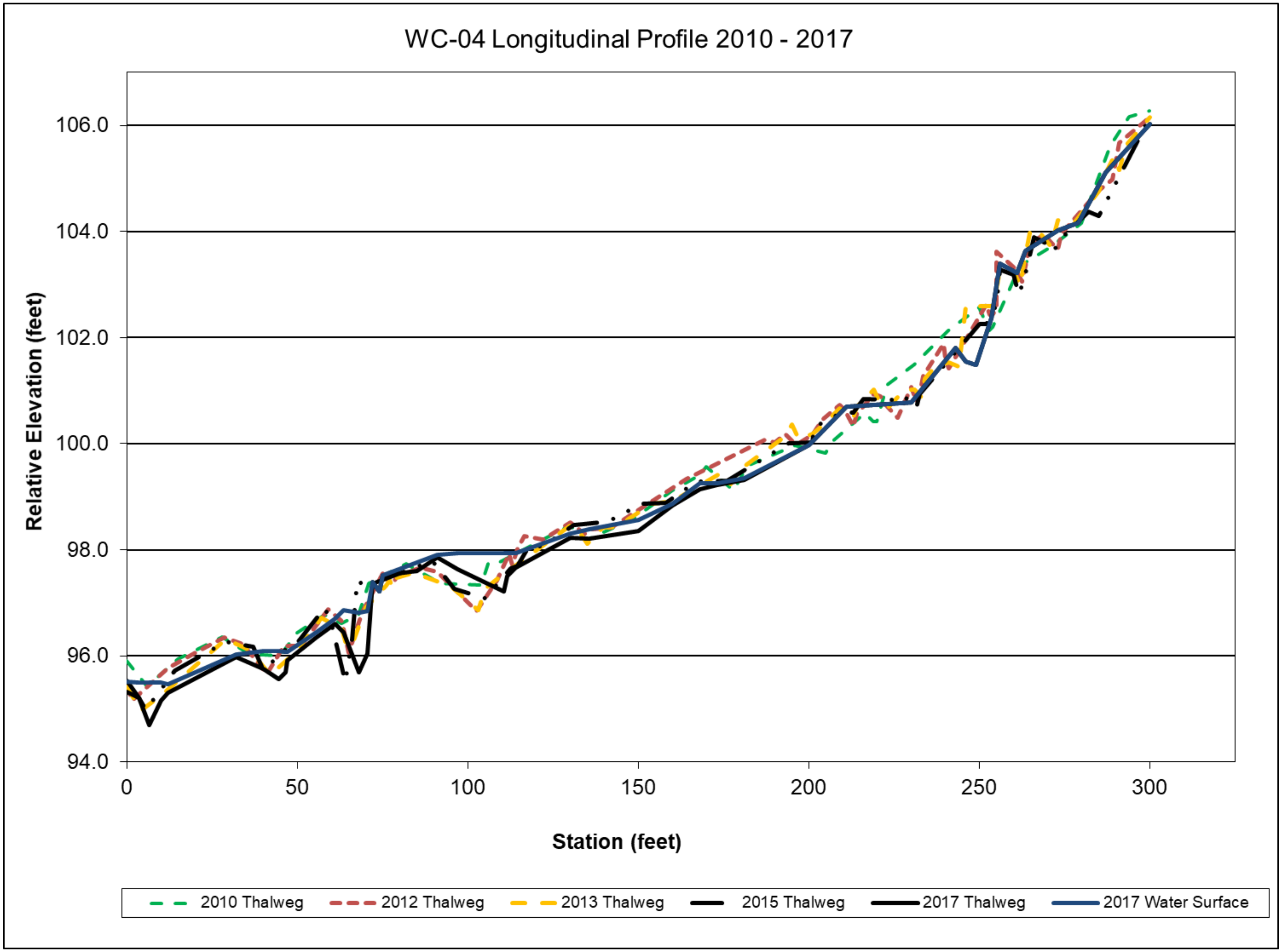

Figure C-6. WC-04 Chart

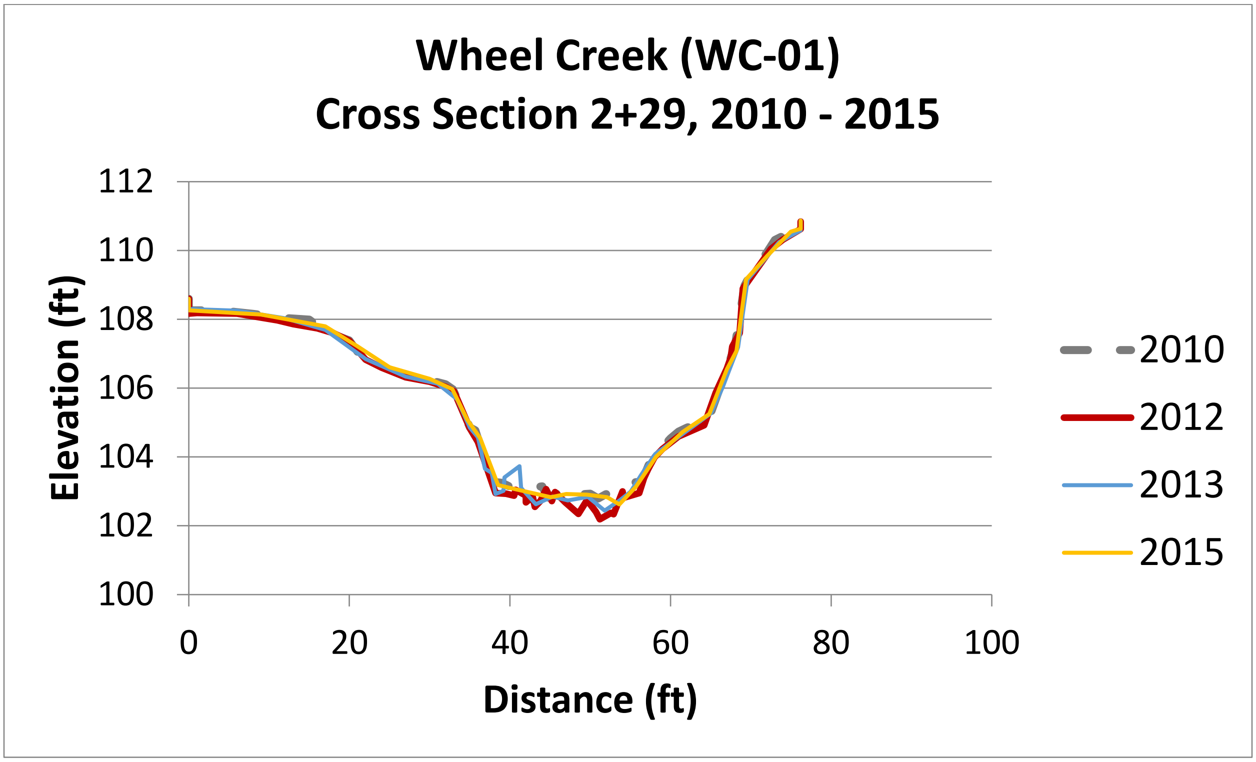

Figure C-7. WC01 Cross Section 1 (Pre-Restoration)

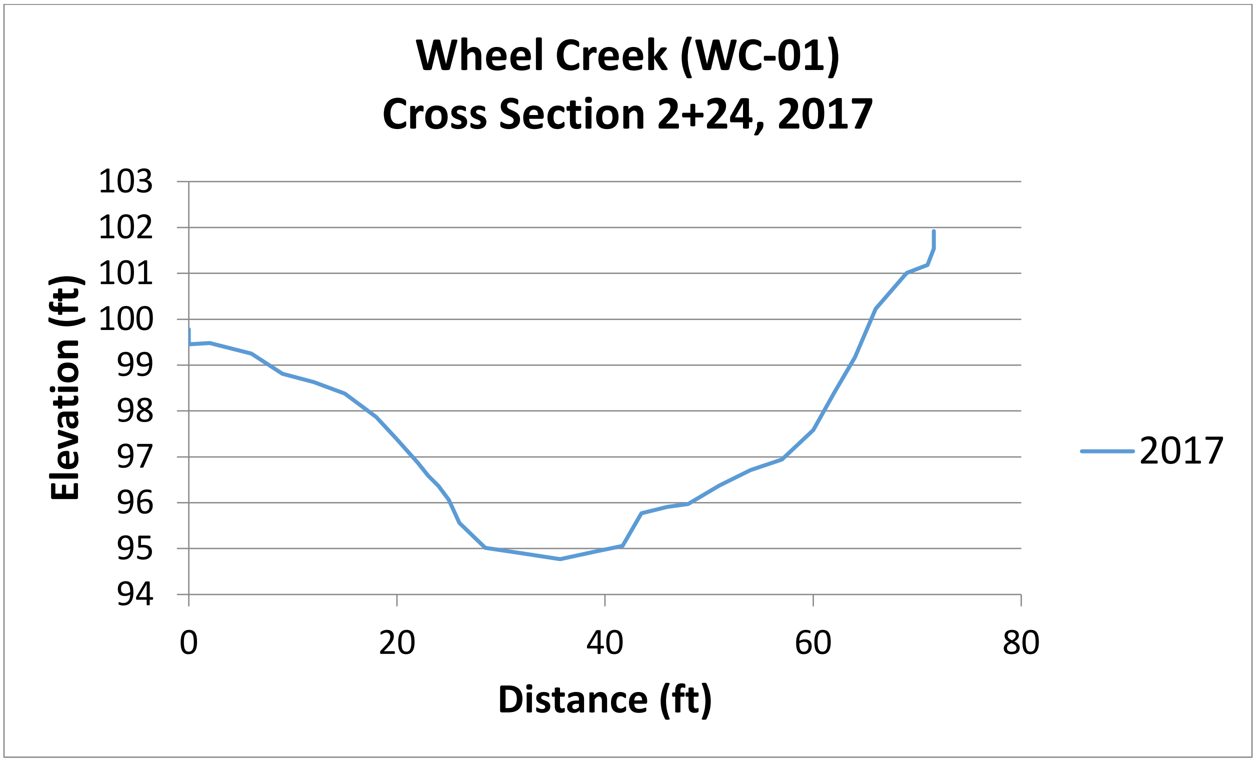

Figure C-8. WC01 Cross Section 1 (Post-Restoration)

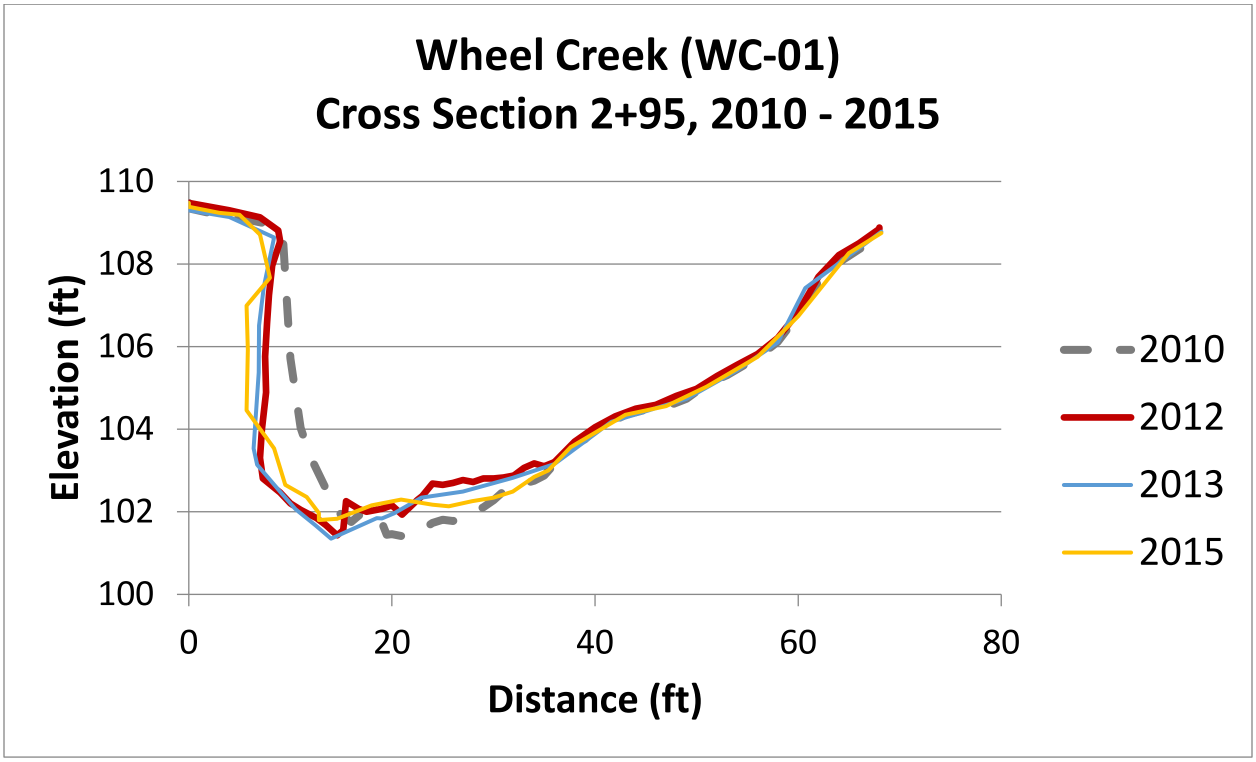

Figure C-9. WC01 Cross Section 2 (Pre-Restoration)

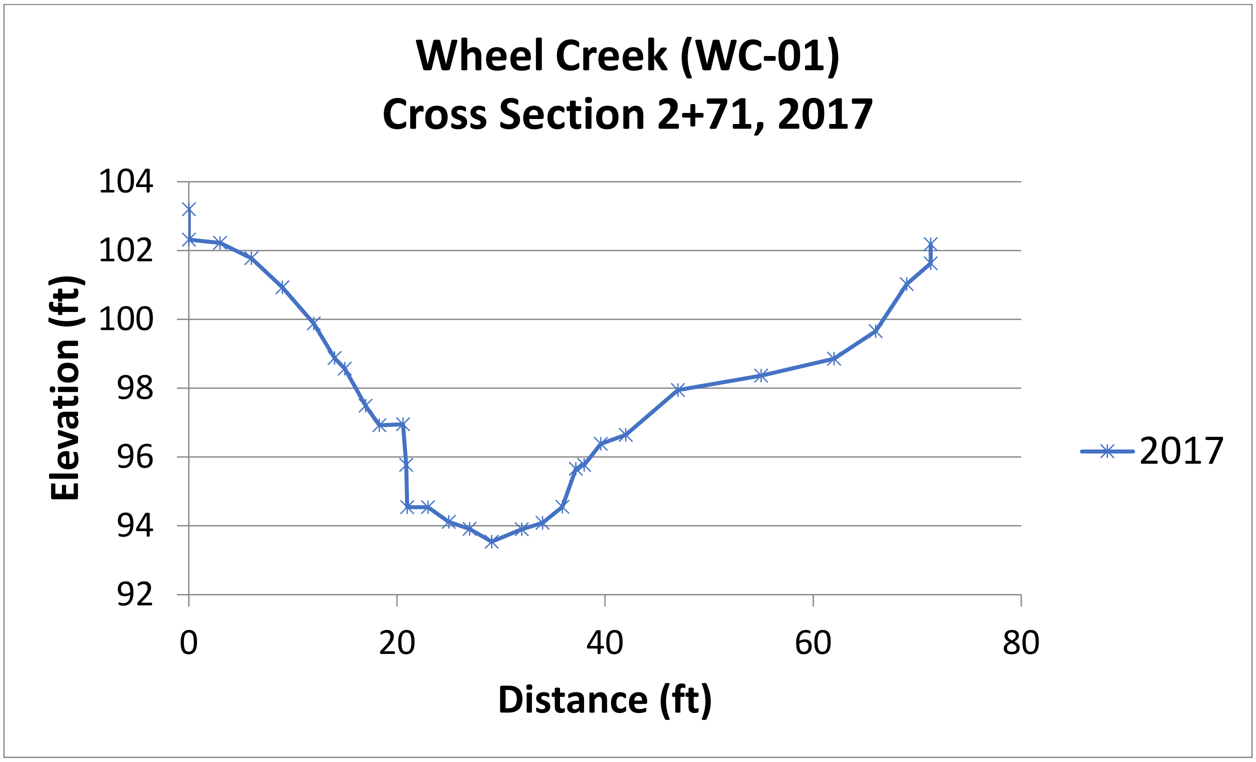

Figure C-10. WC01 Cross Section 2 (Post-Restoration)

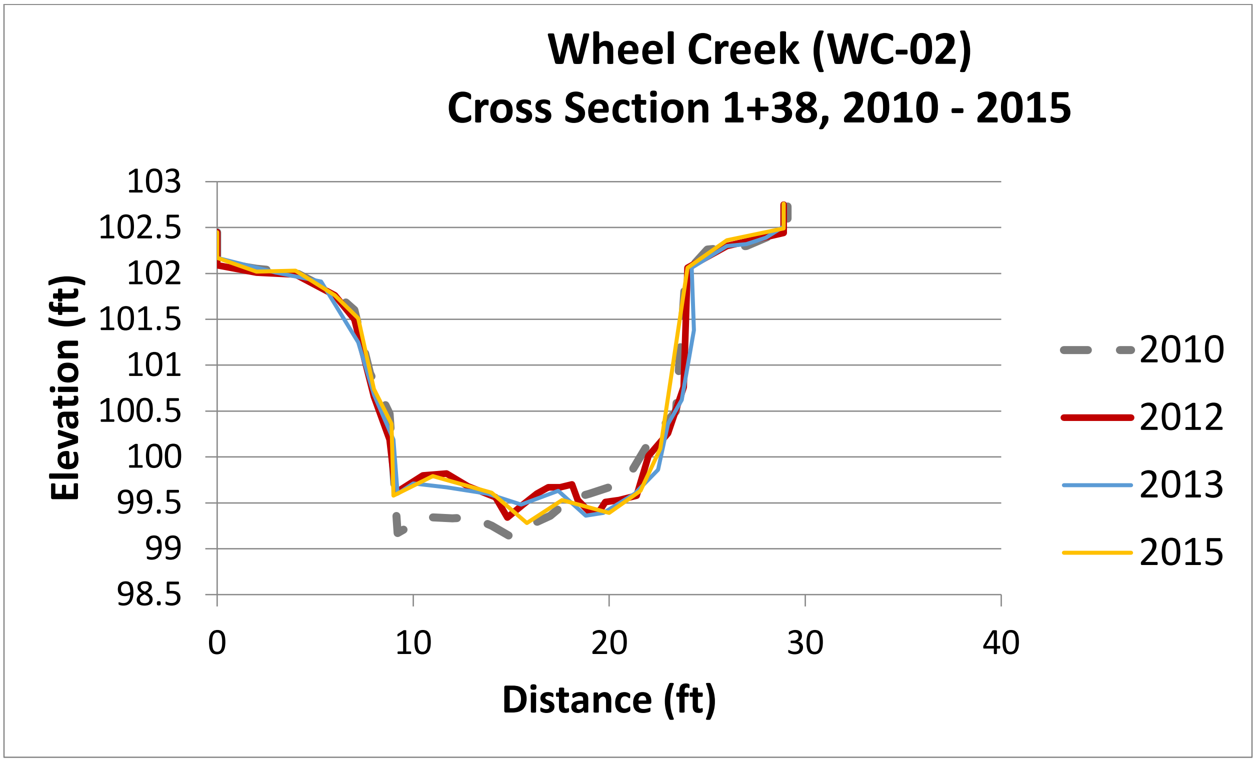

Figure C-11. WC02 Cross Section 1 (Pre-Restoration)

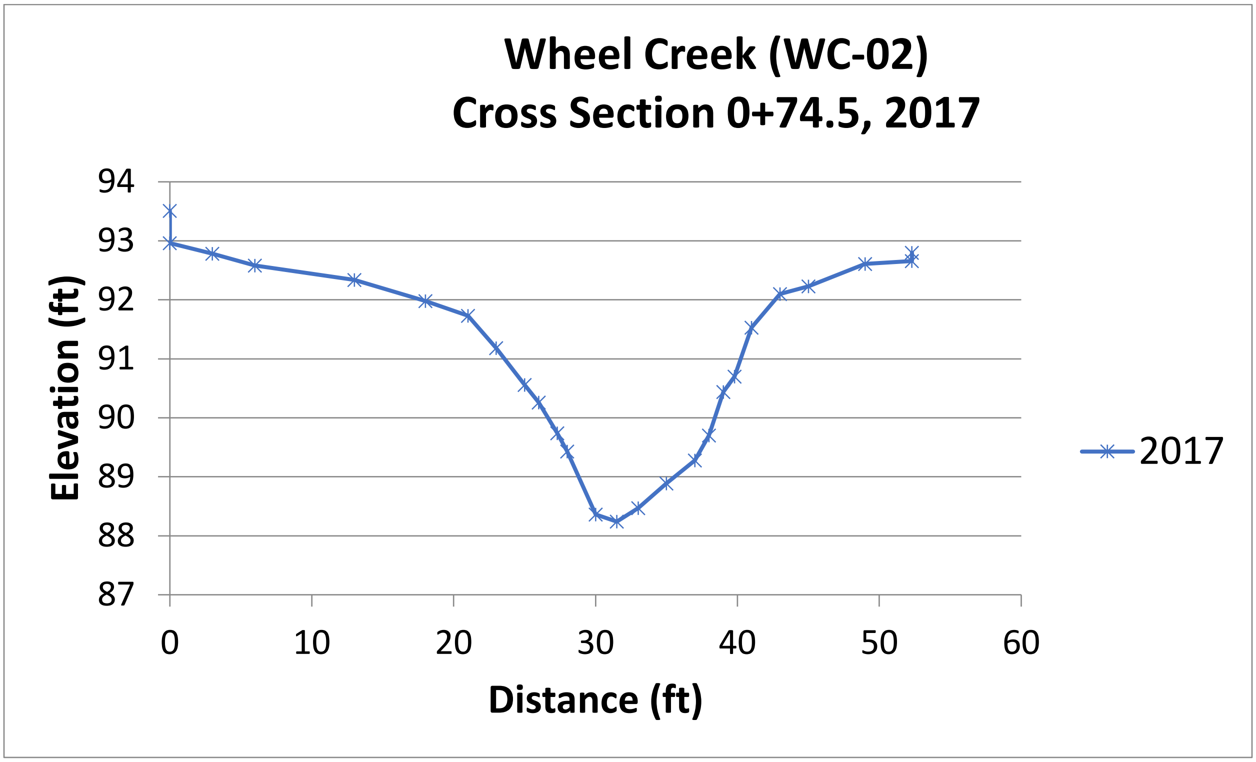

Figure C-12. WC02 Cross Section 1 (Post-Restoration)

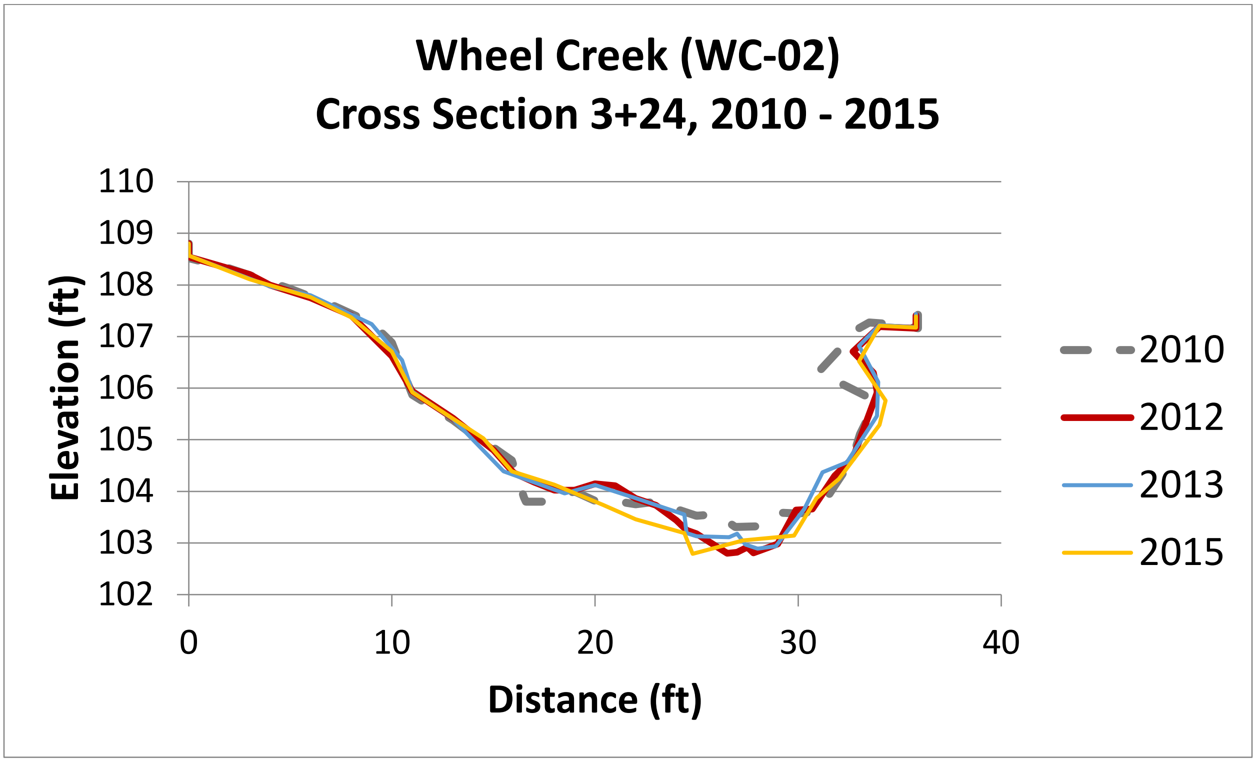

Figure C-13. WC02 Cross Section 2 (Pre-Restoration)

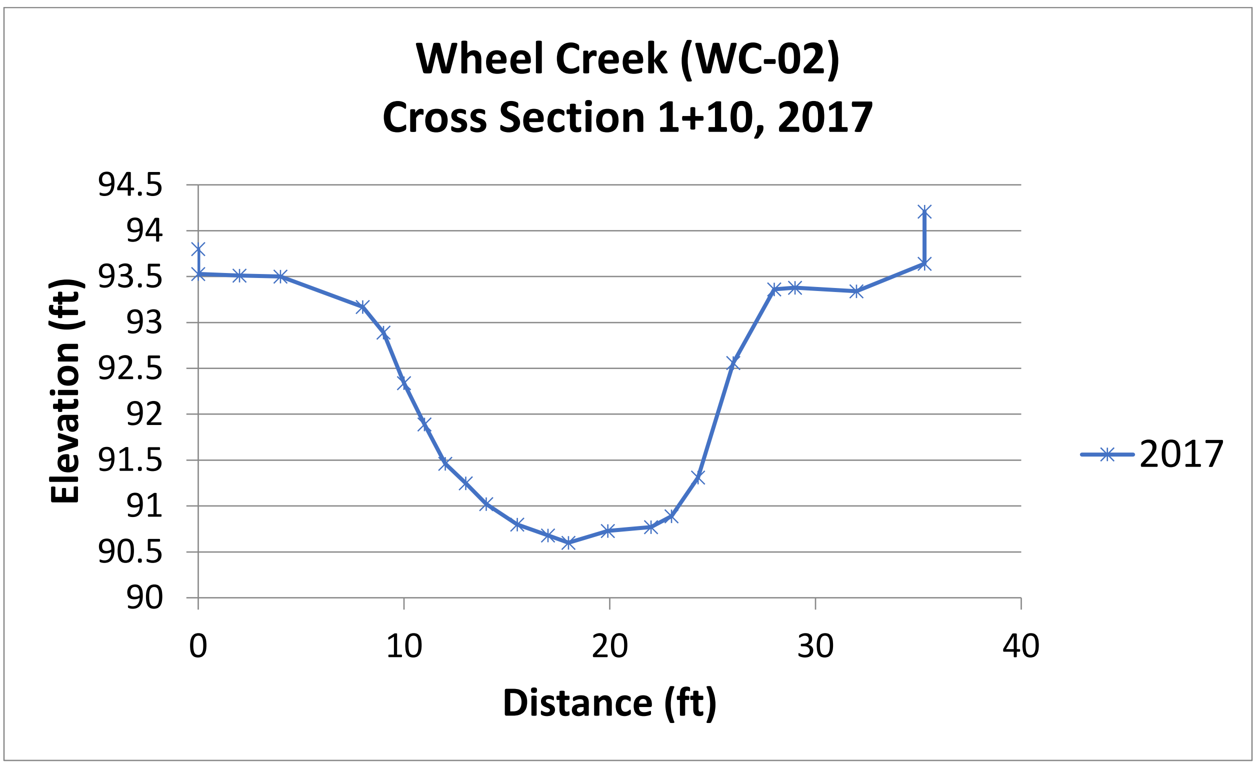

Figure C-14. WC02 Cross Section 2 (Post-Restoration)

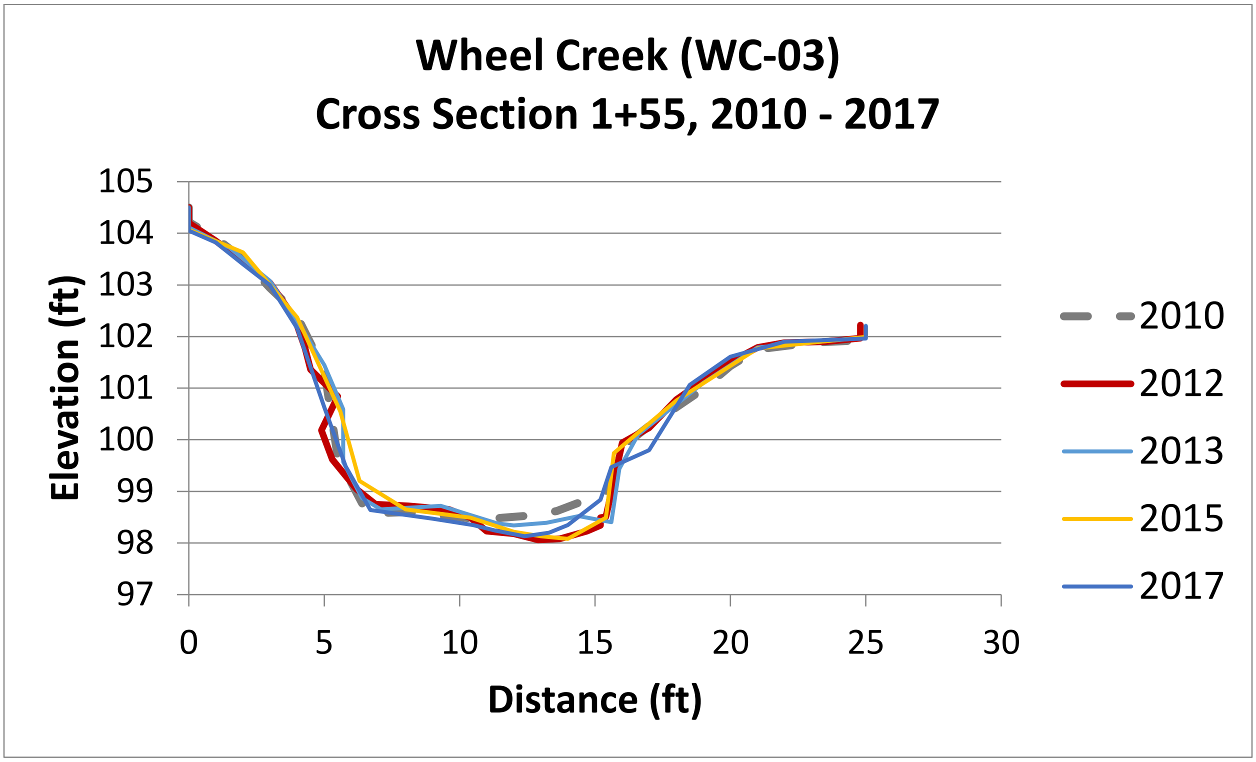

Figure C-15. WC03 Cross Section 1

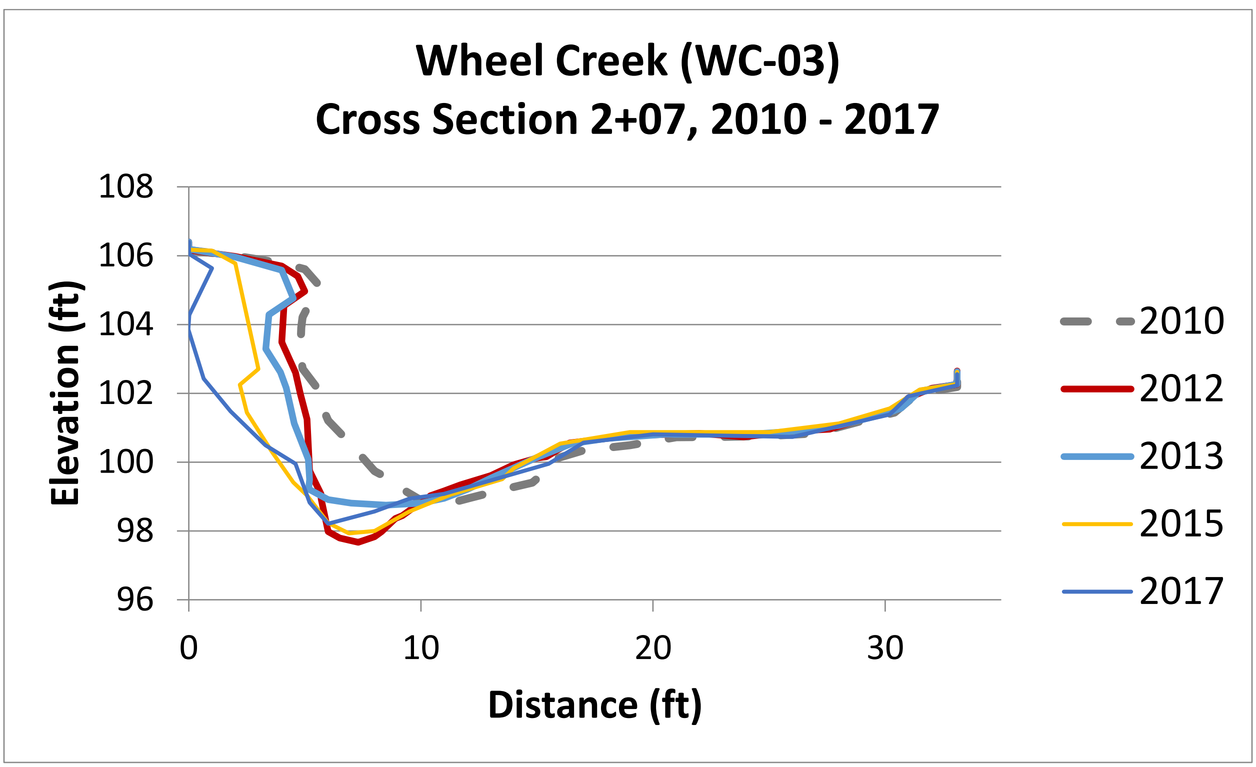

Figure C-16. WC03 Cross Section 2

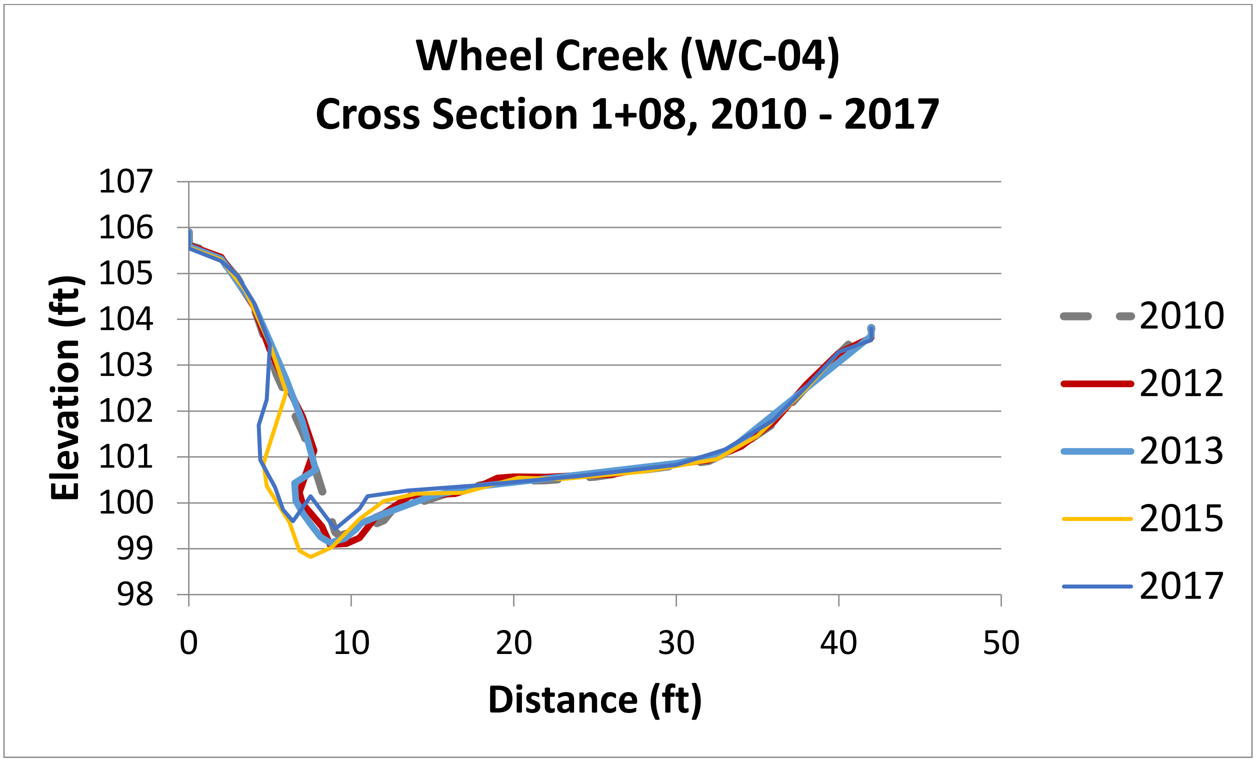

Figure C-17. WC04 Cross Section 1

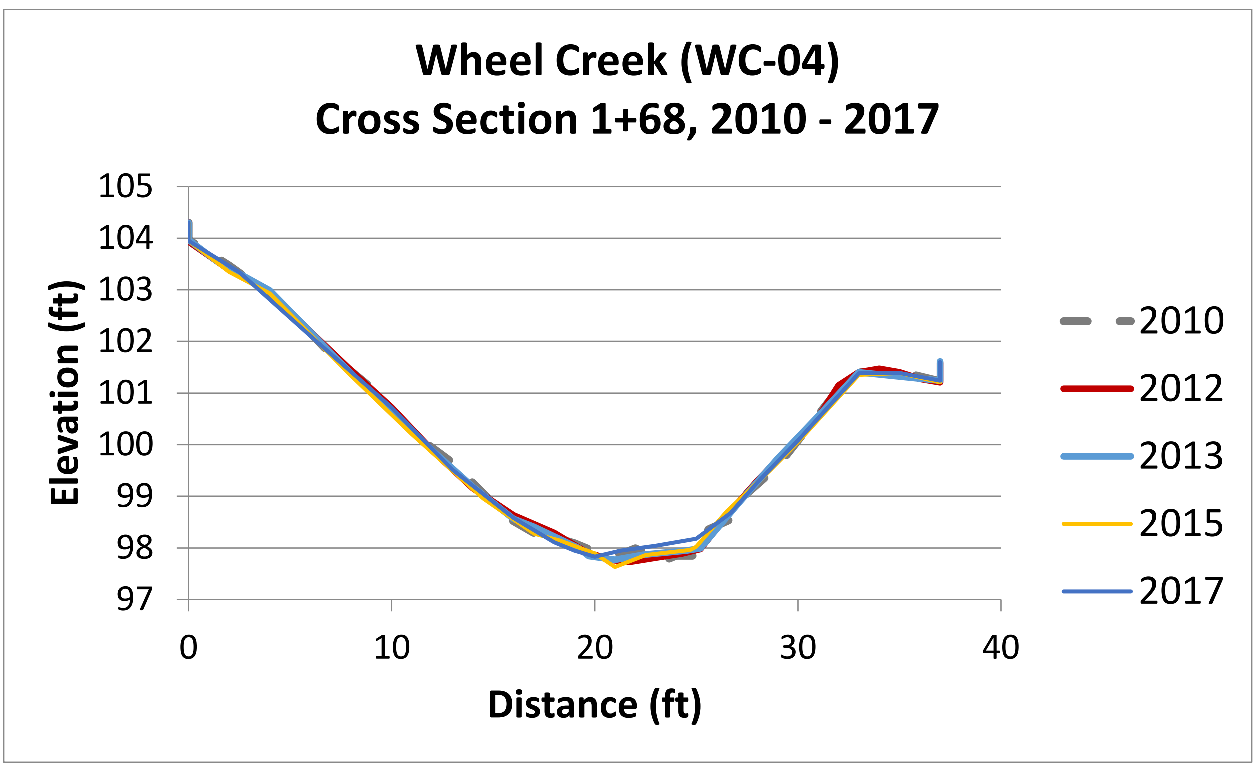

Figure C-18. WC04 Cross Section 2

Table C-3. Particle Size Distribution Pre-Restoration Year 1 – Year 4, Post-Restoration Year 1

	Riffle Feature Surface			***Meander Feature Surface***			***Reachwide***		
Year	**Measure**	**Size (mm)**	**Size Class**	**Measure**	**Size (mm)**	**Size Class**	**Measure**	**Size (mm)**	**Size Class**
				WC01					
2010	D50	39	very coarse gravel	D50	38	very coarse gravel	D50	44	very coarse gravel
2012	D50	56	very coarse gravel	D50	40	very coarse gravel	D50	51	very coarse gravel
2013	D50	49	very coarse gravel	D50	37	very coarse gravel	D50	55	very coarse gravel
2015	D50	50	very coarse gravel	D50	55	very coarse gravel	D50	42	very coarse gravel
2017	*D50*	*52*	*very coarse gravel*	*D50*	*11*	*medium gravel*	*D50*	*25*	*coarse gravel*
2010	D84	120	medium cobble	D84	90	medium cobble	D84	140	large cobble
2012	D84	180	large cobble	D84	77	small cobble	D84	120	medium cobble
2013	D84	130	large cobble	D84	87	small cobble	D84	130	large cobble
2015	D84	160	large cobble	D84	110	medium cobble	D84	150	large cobble
2017	*D84*	*120*	*small cobble*	*D84*	*57*	*very coarse gravel*	*D84*	*90*	*small cobble*
				WC02					
2010	D50	50	very coarse gravel	D50	45	very coarse gravel	D50	49	very coarse gravel
2012	D50	40	very coarse gravel	D50	33	very coarse gravel	D50	28	coarse gravel
2013	D50	51	very coarse gravel	D50	47	very coarse gravel	D50	40	coarse gravel
2015	D50	36	very coarse gravel	D50	26	very coarse gravel	D50	36	very coarse gravel
2017	*D50*	*26*	*coarse gravel*	*D50*	*4.3*	*very fine gravel*	*D50*	*16*	*medium gravel*
2010	D84	98	medium cobble	D84	94	medium cobble	D84	100	medium cobble
2012	D84	80	small cobble	D84	69	small cobble	D84	80	small cobble
2013	D84	88	small cobble	D84	86	small cobble	D84	110	medium cobble
2015	D84	100	medium cobble	D84	100	medium cobble	D84	110	medium cobble
2017	*D84*	*85*	*very coarse gravel*	*D84*	*19*	*medium gravel*	*D84*	*62*	*very coarse gravel*
				WC03					
2010	D50	33	very coarse gravel	D50	8.7	medium gravel	D50	28	coarse gravel
2012	D50	27	coarse gravel	D50	15	medium gravel	D50	23	coarse gravel
2013	D50	27	coarse gravel	D50	29	coarse gravel	D50	35	very coarse gravel
2015	D50	36	very coarse gravel	D50	7.2	fine gravel	D50	26	coarse gravel
2017	*D50*	*26*	*coarse gravel*	*D50*	*17*	*medium gravel*	*D50*	*16*	*medium gravel*
2010	D84	74	small cobble	D84	72	small cobble	D84	75	small cobble
2012	D84	59	very coarse gravel	D84	43	very coarse gravel	D84	72	small cobble

Table C-3. (Continued)									
	Riffle Feature Surface			***Meander Feature Surface***			***Reachwide***		
Year	**Measure**	**Size (mm)**	**Size Class**	**Measure**	**Size (mm)**	**Size Class**	**Measure**	**Size (mm)**	**Size Class**
WC03 (Continued)									
2013	D84	68	small cobble	D84	59	very coarse gravel	D84	130	large cobble
2015	D84	85	small cobble	D84	30	coarse gravel	D84	69	small cobble
2017	*D84*	*59*	*very coarse gravel*	*D84*	*61*	*very coarse gravel*	*D84*	*50*	*very coarse gravel*
WC04									
2010	D50	30	coarse gravel	D50	18	coarse gravel	D50	22	coarse gravel
2012	D50	36	very coarse gravel	D50	15	medium gravel	D50	24	coarse gravel
2013	D50	33	very coarse gravel	D50	1.5	very coarse sand	D50	36	very coarse gravel
2015	D50	35	very coarse gravel	D50	8.3	medium gravel	D50	28	coarse gravel
2017	*D50*	*43*	*coarse gravel*	*D50*	*12*	*medium gravel*	*D50*	*21*	*medium gravel*
2010	D84	80	small cobble	D84	87	small cobble	D84	71	small cobble
2012	D84	64	small cobble	D84	70	small cobble	D84	76	small cobble
2013	D84	57	very coarse gravel	D84	64	small cobble	D84	79	small cobble
2015	D84	66	small cobble	D84	24	coarse gravel	D84	72	small cobble
2017	*D84*	*99*	*small cobble*	*D84*	*26*	*coarse gravel*	*D84*	*68*	*very coarse gravel*

Ecological Condition of Streams in the Wheel Creek Watershed

Harford County, Maryland

Prepared for

Harford County

Department of Public Works

Watershed Protection and Restoration Division

Prepared by

Maryland Department of Natural Resources

Monitoring and Non-Tidal Assessment Division

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The Chesapeake and Atlantic Coastal Bays Trust Fund

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Introduction

Harford County Department of Public Works (DPW) identified the Wheel Creek watershed as a priority restoration opportunity in 2008. In 2009, the County received a Chesapeake and Atlantic Coastal Bays Trust Fund grant to fund stream restorations, stormwater retrofits, and public outreach, along with biological, geomorphological, and water quality monitoring. This report will focus on the biological and physical habitat data collected in this watershed from 2009 - 2016. The Maryland Biological Stream Survey (MBSS), a Maryland Department of Natural Resources (DNR) program, was responsible for collecting and analyzing these data.

The Wheel Creek watershed lies southeast of Bel Air, Maryland, with its headwaters at the Festival Shopping Center on MD Route 24. The watershed drains 435 acres which includes this shopping center, high density residential property, and some forested and agricultural lands. Historically, the watershed has undergone many changes, including a shift from agricultural to urban land cover, with an increase in impervious land cover of 27% over the past three decades (Xian et al. 2011).

Maryland DNR collected ecological data in the Wheel Creek Watershed as part of an agreement between DNR's Resource Assessment Service and Chesapeake and Coastal Services. Data were provided to DPW to assess the effectiveness of several restoration projects, and evaluate ecological lift (if any) in restored areas. In 2009, seven study sites in the Wheel Creek watershed and an eighth control site in an adjacent watershed were selected and sampled prior to construction. These sites were visited three times each year and sampled according to MBSS protocols (Stranko et al. 2015). Due to reduced funding, the number of sites sampled was reduced to the four sites most critical for evaluating the effectiveness of the restoration (ATKI-003-X, ATKI-101-X, ATKI-102-X and LWIN-108-X).

The goal of this sampling program is to evaluate potential effects stream restoration or stormwater retrofits may have on stream ecological conditions. Ecological indicators used to determine such effects may be based on comparisons to reference (a "healthy" stream near the study watershed) and control (usually upstream from the restoration work) sites near the study sites. If the restoration is effective at improving ecological conditions, one would expect to see changes in biological condition over time as illustrated in the Figure 1. The control and study site should mirror one another, then, after construction of the restoration site, conditions should improve in the restored site resulting in similar biological conditions at restored and reference sites. Note that a reference site was not available for this study so comparisons may be made to the control site.

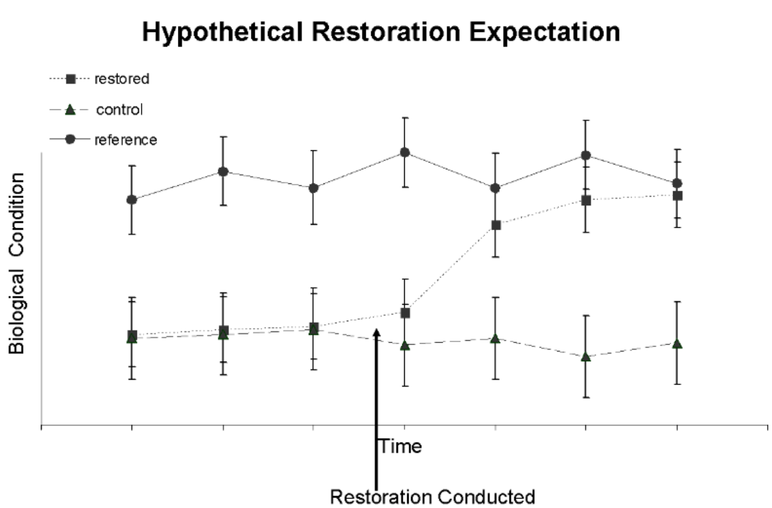

Figure 1 - Hypothetical data from a restored site and reference and control sites

The condition of stream biota depends on several physichochemical, geomorphological, hydraulic, and hydrologic factors (Figure 2). Effective stream and watershed restoration may result in so-called "ecological lift" if the factors beneath the biology are improved and sustained effectively (Harman et al. 2012).

This document will detail the ecological monitoring results performed by the MBSS from 2009 through 2016. It will help determine if improvements in the Wheel Creek Watershed lead to improvements in habitat and biological condition over the years of the project.

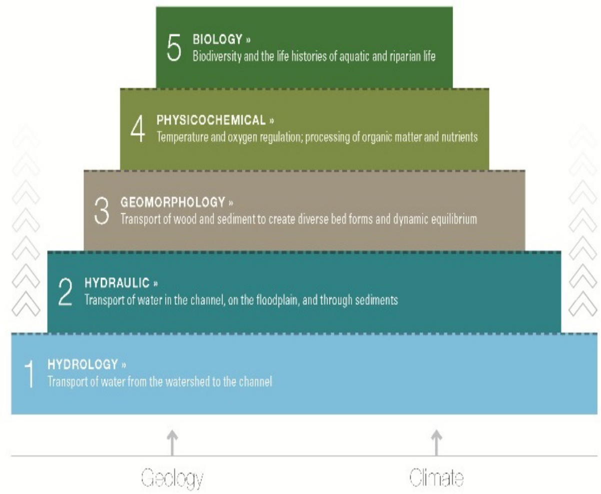

Figure 2 – The Stream Function Pyramid

Study Area and Design

The Wheel Creek watershed contains 2.2 stream miles and lies within the Atkisson Reservoir watershed, a subwatershed of the Bush River Basin. The restoration area includes Wheel Creek and a small unnamed tributary. Several restoration and retrofit projects are being implemented along both waterways. Figure 3 shows an overview of the watershed and the locations of each monitoring and restoration site. Sites ATKI-101-X, ATKI-102-X, ATKI-105-X and ATKI-107-X are on Wheel Creek and sites ATKI-003-X, ATKI-004-X and ATKI-006-X are on an unnamed tributary to Wheel Creek. The control site, LWIN-108-X is in an adjacent watershed on an unnamed tributary to Lower Winters Run. Sampling site and catchment information is in the Appendix.

Figure 3 - Wheel Creek Watershed with restoration and retrofit locations and MBSS, USGS and Harford County monitoring sites. The MBSS control site (right) lies within the Lower Winters Run watershed. Site and catchment data are contained in the Appendix.

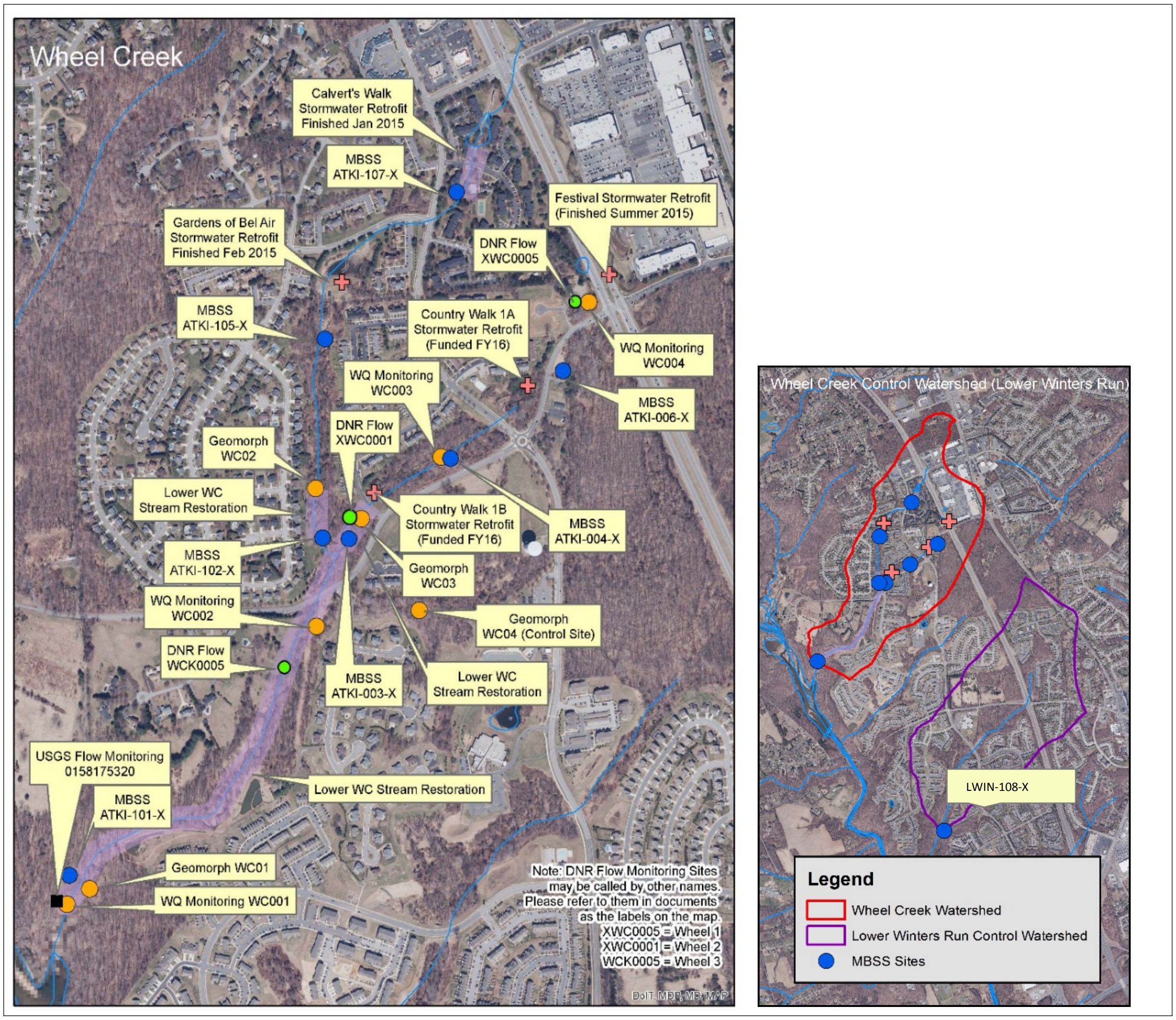

Table 1 – Wheel Creek Watershed Implementation Schedule

Name	Project Type	Start Date	Completion Date
Gardens of Bel Air (Pond A)	Stormwater Retrofit	September 2012	December 2012
Calverts Walk (UMS-1)	Stream Restoration	January 2013	April 2013
Festival of Bel Air (Pond C)	Stormwater Retrofit	May 2015	August 2015
Country Walk 1A (Pond D)	Stormwater Retrofit	September 2015	December 2015
MMS-5, B-4, MB-1	Stream Restoration	December 2015	February 2016
Water Quality Facilities	Water Quality Facilities	December 2015	March 2016
Lower Wheel Creek	Stream Restoration	September 2016	July 2017
Country Walk 1B (Pond E)	Stormwater Retrofit	December 2016	July 2017

Methods

Monitoring in the Wheel Creek watershed was performed according to MBSS protocols and included benthic macroinvertebrate and fish community sampling and physical habitat assessment. Each 75 m site was visited twice per year for spring and summer sampling (Stranko et al. 2015).

Land Cover Assessment

Upstream catchments for each site were delineated in ArcMap using 1:100,000 scale maps. Land cover was estimated using 2001 and 2011 data contained in the National Land Cover Database (Xian et al. 2011).

Physical Habitat Assessment

MBSS Physical habitat assessments (Stranko et al. 2015) were performed during the summer index period. Habitat parameters were rated visually on a scale of 0-20 (Instream Habitat, Epifaunal Substrate, Velocity/Depth Diversity, Pool Quality) or as a percentage (Embeddedness, Shading). Other habitat measures included discharge (cfs) and Bank Erosion (m^2).

Benthic Macroinvertebrate Sampling and Data Analysis

Benthic macroinvertebrate sampling was conducted during the spring index period (March 1 – April 30) of each year. Each site has been sampled annually since 2009 with the exception of ATKI-107 in 2013 when sampling paused due to in-stream construction at the Calverts Walk (UMS-1) restoration site. Twenty square feet of the best available habitat was sampled using a 500 micron mesh D-net. Samples were field preserved in ethanol and transported to the MDNR laboratory for processing. Each sample was subsampled to approximately 100 organisms and identified lowest practical taxon – primarily genus.

Benthic Indices of Biotic Integrity (BIBI) were calculated for each site. Raw values for six community metrics were calculated and scored based on reference conditions for the Piedmont Physiographic Province (Table 2). Each metric has an expected response to increasing or decreasing perturbation. Metric descriptions can be found in Southerland et al. (2005). BIBI scores and narrative stream health ratings are derived from the average of all metric scores (Table 3).

Table 2 – MBSS Benthic Macroinvertebrate IBI metrics and scoring criteria for the Piedmont Physiographic Province

Metric	Score		
	5	3	1
Total number of taxa	≥25	15-24	<15
Number of EPT taxa	≥11	5-10	<5
Number Ephemeroptera taxa	≥4	2-3	<2
% Intolerant taxa	≥51	12- <51	<12
Percent Chironomidae taxa	≤24	>24-63	>63
Percent clinger taxa	≥74	31- <74	<31

Table 3 – MBSS Benthic Macroinvertebrate IBI score range and stream health rating

BIBI score	Stream Health Rating
4-5	Good
3-3.9	Fair
2-2.9	Poor
1-1.9	Very Poor

Fish Sampling and Data Analysis

Fish were sampled during the summer index period (June 1 – September 30) of each year. The four sites sampled in 2016 have each been sampled annually since 2009. The other sites were sampled annually 2009-2015 with the exception of ATKI-107 in 2013 when sampling paused due to in-stream construction at the Calverts Walk (UMS-1) restoration site. Fish were sampled using block nets and two-pass electrofishing. All collected fish greater than or equal to 30mm in length were identified in the field by MBSS taxonomists, enumerated and released.

As with the BIBIs, fish Indices of Biotic Integrity (FIBI) were calculated for each fish community sample (Southerland et al. 2005). Six fish metrics and their corresponding scores are listed in Table 4. FIBI score ranges and narrative stream health ratings are listed in Table 5.

Table 4 – MBSS Fish IBI metrics and scoring criteria for the Piedmont Physiographic Province

Metric	Score		
	5	3	1
Fish Abundance	≥1.25	.25-1.24	<0.25
Number of benthic species	≥0.26	0.09-0.25	<0.09
Percent tolerant	≤45	46-68	<68
Biomass	≥8.6	4-8.5	<4
Percent lithophilic spawners	≥61	32-60	>32
Percent generalist, ominvores, and insectivores	≤80	81-99	100

Table 5 – MBSS Fish IBI score range and stream health rating

FIBI score	Stream Health Rating
4-5	Good
3-3.9	Fair
2-2.9	Poor
1-1.9	Very Poor

Other Fauna

Crayfish and herpetofauna were sampled at each site and taxa were recorded as a simple count or on a presence/absence basis, respectively. The presence of certain crayfish species may provide insight into stress from competition with exotic species. Some herpetofauna species have strict environmental requirements, so the presence of these species may indicate higher quality habitats.

Results

Site Catchments and Land Cover

Site catchment area for Wheel Creek sites ranged from 393 ac at ATKI-101-X to 50 ac at ATKI-107-X (Appendix). The catchment of LWIN-108-X was 412 ac – the largest of all the sites. It is important to note that MBSS FIBIs are more a reliable indicator of fish community condition for sites with catchments > 300 ac. FIBIs from sites with smaller catchments may be used to evaluate trends but should not be used as a stand-alone indicator of stream health.

Catchments for all Wheel Creek sites (2011 land cover data) contained mostly urban land, with some forest and agricultural land. Forested land cover in each site's catchment ranged from 27.4% at ATKI-

107-X to 13.1% at ATKI-102-X. Urban land cover ranged from 82.3% at ATKI-102 to 67.8% at ATKI-101-X. Forested land cover in all Wheel Creek catchments declined between 2001 and 2011, with the greatest loss (10.7%) in ATKI-101-X. The control site's catchment (LWIN-108-X) contained 23.9% forested and 73% urban land. Forested land cover in this site's catchment increased by 0.5% between 2001 and 2011. More accurate land cover data may be provided by DPW.

Physical Habitat

Most physical habitat parameters in both the Wheel Creek sites and the Control site were in the Poor, Marginal or Suboptimal categories (Appendix). Instream Habitat – a measure of fish habitat quality – was rarely rated Good among all years. Instream Habitat was generally rated higher at the Control site. Epifaunal Substrate – a measure of benthic macroinvertebrate habitat suitability – was most often rated Poor, Marginal or Sub-optimal, suggesting that habitat for these organisms was generally lacking.

Biological Communities

Benthic Macroinvertebrates

A total of 18 genera within 52 families and 21 orders were sampled among all sites and all years (Appendix). The most abundant genera and their average relative abundances were *Orthocladius sp.* (Diptera; 26.1%), *Cheumatopsyche sp.* (Trichoptera; 6.8%), *Chimarra sp.* (Trichoptera; 6.4%), *Hydropsyche sp.* (Trichoptera; 5.3%) and *Stenelmis sp*. (Coleoptera; 3.6%). These five taxa are all considered tolerant or moderately-tolerant to pollution. Fourteen genera (13%) were found at all eight sites during at least one year of sampling.

The presence of intolerant benthic taxa can offer a great deal of insight into overall stream health. The number of intolerant taxa ranged from 3 at ATKI-105-X and ATKI-107-X to 11 at LWIN-108-X, with a total of 24 intolerant taxa occurring among all sites and all years. The cumulative list of intolerant taxa included *Oulimnius sp.* and *Ectopria sp.* (Coleoptera), *Procambarus sp.* (Decapoda), *Potthastia sp., Microspectra sp., Heterotrissocladius sp., Krenosmittia sp., Neoplasta sp., Prosimulium sp., Dicronota sp.* (Diptera), *Maccaffertium sp.* (Ephemeroptera), *Nigronia sp.* (Megaloptera), *Stylogomphus sp.* (Odonota), *Leuctra sp.* and *Amphinemura sp.* (Plecoptera), *Polycentropus sp. , Neureclipsis sp., Nyctiophylax sp., Neophylax sp., Glossosoma sp., Diplectrona sp., Dolophilodes sp. and Lepidistoma sp.* (Trichoptera) and *Girardia sp.* (Tricladida).

Fish

A total of 22 fish species were collected at all 8 sites across all years (Appendix). Average taxa richness ranged from 17 at LWIN-108-X to 2 at ATKI-107-X. Two fish species – creek chub and blacknose dace – were found at all sites across all years. Blue ridge sculpin was found at seven of the eight sites. Forty five percent of the sampled fish species were found at only one site. Six of these were only found at ATKI-101-X and the other 4 were only found at LWIN-108-X.

Most fish species were considered tolerant or moderately-tolerant to pollution. Intolerant species included blue ridge sculpin, margined madtom, river chub, redbreast sunfish, common shiner and fallfish. The highest number of intolerant fish species (5) was found at LWIN-108-X.

Indices of Biotic Integrity

Across all years, average BIBIs reflected Poor or Very Poor conditions at all sites, including the control site. Scores ranged from 3.0 at LWIN-108-X to 1.0 at ATKI-004-X. Most sites were rated Very Poor by BIBIs. Only LWIN-108-X was rated Fair (BIBI = 3.0 in 2010, 2012, and 2016). No sites were rated Good in any year. BIBI scores changed very little at all eight sites across the years (Figure 4).

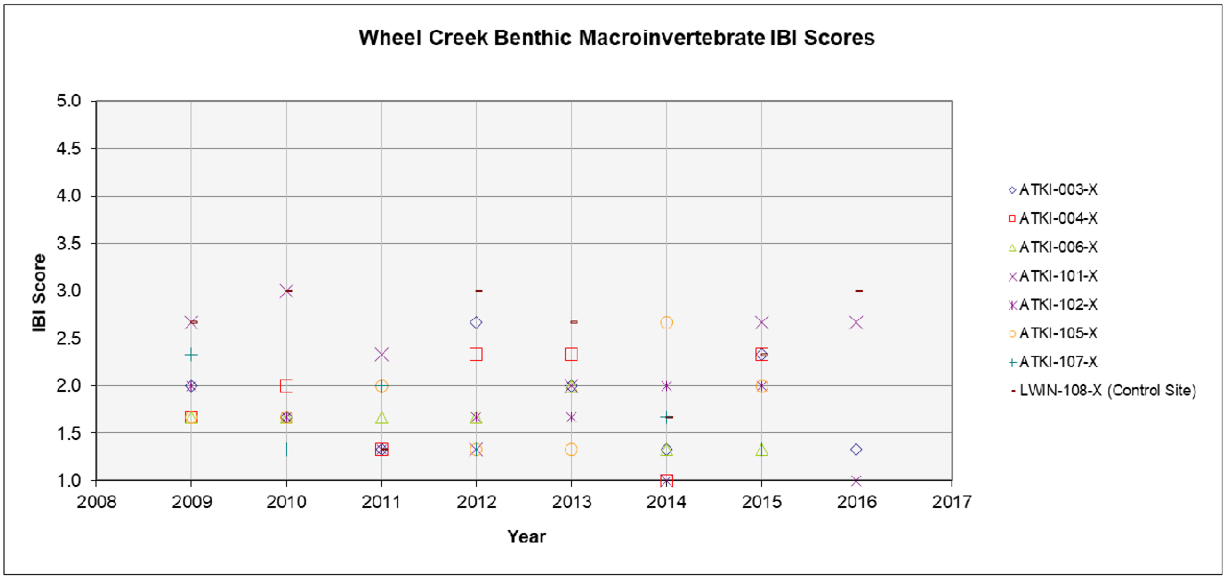

Figure 4 – Benthic IBI scores for Wheel Creek and control sites, 2009 – 2016.

Average FIBIs indicated conditions ranging from Good at ATKI-101-X, ATKI-102-X, and LWIN-108-X to Very Poor at ATKI-107-X. Mean FIBIs at all other sites indicated Fair conditions. FIBI scores changed very little at all 8 sites across the years (Figure 5).

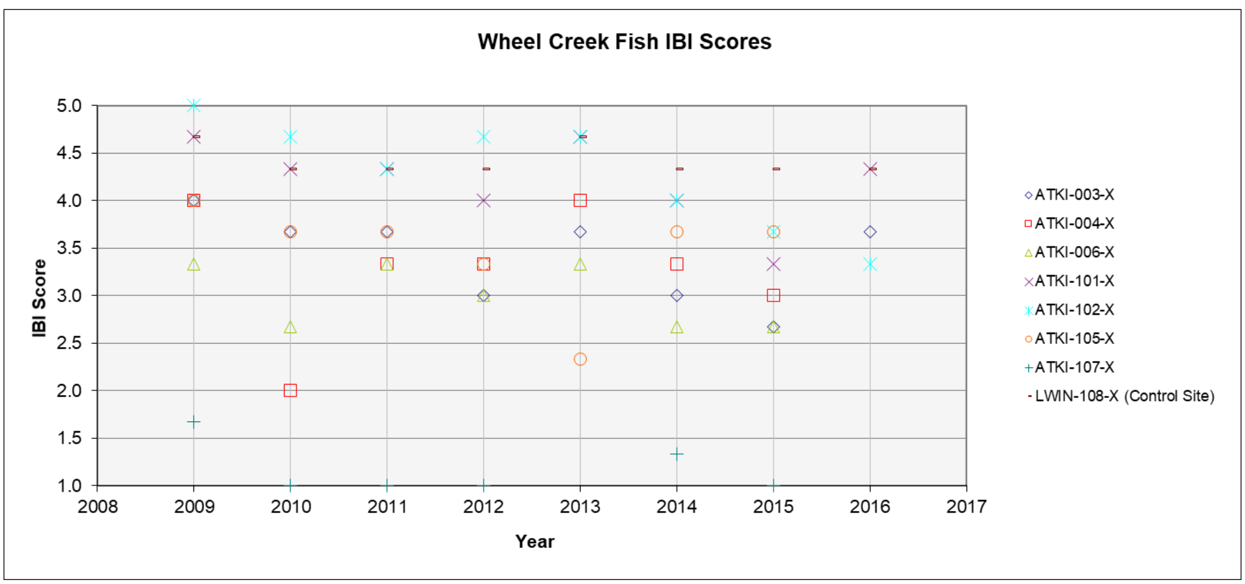

Figure 5 – Fish IBI scores for Wheel Creek and control sites, 2009 – 2016.

Crayfish

A total of 7 crayfish species were sampled among all 8 sites. Common species included the common crayfish (*Cambarus bartonii bartonii*), virile crayfish (*Orconectes virilis*), spiny cheek crayfish (*Orconectes limosus*) and unknown Procambarus sp. (*Procambarus sp.*). The virile crayfish – a non-native and invasive species – was found at all sites except ATKI-107-X. This species should be considered a threat to native species as it may expand its range throughout the Wheel Creek Watershed.

Herpetofauna

Reptile and amphibian species counts (presence/absence) ranged from 12 at ATKI-101-X to 5 at ATKI-006-X. Most species are somewhat cosmopolitan and fairly tolerant of disturbed habitats. However, the northern dusky salamander, northern two-lined salamander and northern red salamander are all stream-dwelling species with somewhat strict environmental conditions (with the possible exception of the northern two-lined salamander). Any stream or watershed BMPs that result in stream channel or floodplain (e.g., vernal pool) habitat improvements may directly benefit some herpetofauna species.

Discussion

Streams within the Wheel Creek Watershed are typical of those in urbanized areas of Maryland's Piedmont. At several sites, benthic macroinvertebrate and fish communities – the best indicators of overall stream health - are degraded by multiple stressors resulting from land disturbance, channel alternation and all the stressors associated with upstream impervious surfaces. The presence of some sensitive organisms such as mayflies, stoneflies, fallfish, and northern red salamanders suggests that water quality and habitat at some sites is less degraded than at others. During some sampling years, BIBIs and FIBIs at some sites (e.g., ATKI-102-X and ATKI-101-X) indicate better conditions. Indices during some years were comparable to the control site (LWIN-108-X). These sites may benefit most from restoration projects since they are less degraded than others.

It is likely too early to tell if restoration work conducted in early-mid 2015 has had any effect on stream biota or habitat. Further ecological sampling using MBSS protocols will provide valuable insight into the effectiveness of additional restoration work.

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ATKI-003-X

ATKI-003-X in spring 2016

Coordinates

Latitude	*Longitude*
39.48825	76.33337

Land Use

	Catchment	
Acres	105	
	% of Catchment	
Land Cover Type	*2001 NLCD*	*2011 NLCD*
Forest	27.8	22.7
Agriculture	14.1	2.3
Urban	57.5	75.0
Other	0.6	0

Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale. Score ranges are: 0-5 (poor), 6-10 (marginal), 11-15 (sub-optimal) and 16-20 (optimal)

Parameter	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Instream habitat (0-20)	9	10	17	12	14	12	12	8
Epifaunal substrate (0-20)	8	14	16	11	12	13	13	11
Velocity/Depth Diversity (0-20)	11	11	14	13	13	11	12	11
Pool Quality (0-20)	11	11	16	12	13	13	12	14
Riffle Quality (0-20)	8	8	9	12	12	12	11	9
Shading (%)	85	90	90	80	65	70	80	75
Embeddedness (%)	40	35	15	60	45	40	35	50
Discharge (cfs)	0.15	0.13	0.12	1.93	0.06	1.36	0.14	0.02
Bank Erosion (m^2)*	60.0	67.8	14	40.8	87.1	66.5	60.0	6.5

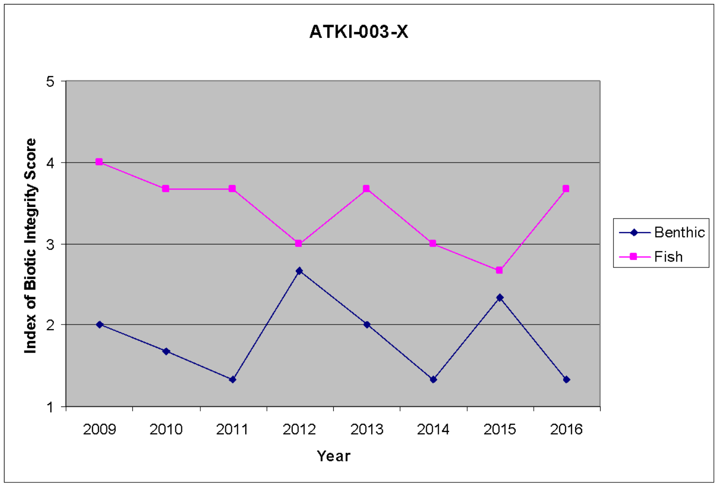
* = Total area of eroded stream banks (sum of left and right banks)

Biology

Indexes of Biotic Integrity.

	Score							
Metric	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
BIBI	2.00	1.67	1.33	2.67	2.00	1.33	2.33	1.33
FIBI	4.00	3.67	3.67	3.00	3.67	3.00	2.67	3.67

IBI scores less than 2 are rated very poor, 2 to 2.9 are rated poor, 3 to 3.9 are rated fair, and 4 to 5 are rated good.



Fish species collected and their annual abundance.

Species	*Tolerance*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Blue ridge sculpin	I	89	62	37	25	25	32	20	45
Creek chub	T	231	99	106	87	120	60	61	239
Blacknose dace	T	97	44	52	73	51	64	61	327

Tolerance values are represented as I, M, or T. Intolerant species are represented by I, moderately tolerant species are represented by M, and tolerant species are represented by T.

Crayfish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Virile crayfish *(Orconectes virilis*)	3	4	2	28	7	7	6	16
Unknown Procambarus (*Procambarus sp.*)	0	0	0	1	0	0	0	0

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Anura (Frogs and Toads)	Pickerel frog	A	A	P	P	P	A	A	P
	Northern green frog	A	A	A	P	P	P	P	P
	Cope's gray treefrog	A	A	A	P	P	A	A	A
	Northern spring peeper	A	A	A	A	A	A	P	A
Caudata (Salamanders and Newts)	Eastern red-backed salamander	P	A	A	A	A	A	A	A
	Northern red salamander	P	A	P	A	A	A	P	A
	Northern two-lined salamander	P	A	P	P	P	P	P	P
	Northern dusky salamander	A	A	A	P	A	A	A	A

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*Tolerance*	*2009 RA*	*2010 RA*	*2011 RA*	*2012 RA*	*2013 RA*	*2014 RA*	*2015 RA*	*2016 RA*
Annelida	Haplotaxida	Enchytraeidae	*n/a*	T	---	---	---	---	*0.9	---	---	---
		Naididae	*n/a*	T	---	---	*1.0	---	---	---	---	---
	Lumbriculida	Lumbriculidae	*n/a*	M	---	*0.8	---	---	---	---	---	---
	Tubificida	Tubificidae	*n/a*	T	---	*1.7	---	---	---	---	---	---
			Spirosperma	M	---	---	---	0.9	---	---	---	---
Arthropoda	Amphipoda	Crangonyctidae	*Stygobromus*	M	1.8	---	---	---	---	---	---	---
	Coleoptera	Elmidae	*Ancyronyx*	T	---	---	---	---	---	0.9	---	---
			Stenelmis	T	6.4	5	4.8	15.8	18.1	8.8	18.4	9.1
		Dytiscidae	*Neoporus*	M	---	0.8	---	---	---	---	---	---
		Psephenidae	*Ectopria*	I	---	---	---	0.9	---	---	---	---
	Collembola	Isotomidae	*Isotomurus*	M	---	---	---	---	---	0.9	---	---
	Diptera	Ceratopogonidae	*n/a*	M	*1.8	---	*1.0	---	---	---	---	---
		Chironomidae	*Ablabesmyia*	T	---	0.8	1.0	---	---	---	1.6	0.8
			Brillia	T	---	---	---	---	---	---	---	1.7
			Chaetocladius	T	12.8	---	---	2.6	---	---	---	1.7
			Chironomini	M	---	*0.8	---	---	---	---	---	---

Phylum	*Order*	*Family*	*Genus*	*Tolerance*	*2009 RA*	*2010 RA*	*2011 RA*	*2012 RA*	*2013 RA*	*2014 RA*	*2015 RA*	*2016 RA*
			Chironomus	M	---	---	---	0.9	---	---	---	11.6
			Corynoneura	M	---	0.8	---	---	0.9	---	---	---
			Cryptochironomus	T	---	---	---	---	---	---	0.8	---
			Diamesa	T	---	---	---	---	---	---	0.8	0.8
	Diptera	Chironomidae	*Diamesinae*	T	---	---	---	---	---	---	---	3.3
			Dicrotendipes	T	---	---	---	---	---	---	1.6	---
			Eukiefferiella	M	---	6.7	---	6.1	---	---	---	0.8
			Heterotrissocladius	I	---	0.8	---	---	---	---	---	---
			Hydrobaenus	T	0.9	---	16.3	0.9	11.2	2.6	---	1.7
			Krenosmittia	I	---	---	---	---	---	---	2.4	---
			Micropsectra	I	1.8	20	---	10.5	---	0.9	---	4.1
			Orthocladiinae	T	*0.9	*0.8	*1.0	*3.5	*1.7	*2.6	*3.2	2.5
			Orthocladius	T	19.3	25.8	58.7	16.7	19.0	50.9	22.2	30.6
			Paramerina	M	---	---	---	---	---	---	0.8	---
			Parametriocnemus	M	1.8	---	---	0.9	---	4.4	---	---
			Paraphaenocladius	M	0.9	---	---	---	---	---	---	---
			Paratanytarsus	T	---	---	1.0	---	3.4	---	---	---
			Paratendipes	M	---	---	---	0.9	---	---	---	---
			Phaenopsectra	T	---	---	---		0.9	0.9	---	---
			Polypedilum	M	7.3	13.3	2.8	5.3	---	---	1.6	8.3
			Rheocricotopus	M	---	---	---	---	---	---	---	4.1
			Rheotanytarsus	T	4.6	---	1.9	2.6	---	0.9	14.4	---
			Sympotthastia	T	---	---	---	---	4.3	8.8	---	---
			Tanypodinae	T	---	---	---	---	---	---	*0.8	*0.8
			Tanytarsini	M	---	---	---	*0.9	---	---	*3.1	---
			Tanytarsus	M	2.8	---	1.9	---	---	0.9	---	0.8
			Stenochironomus	T	---	---	---	---	---	---	0.8	---
			Thienemanniella	M	---	2.5	---	---	---	---	---	---
			Thienemannimyia Group	T	*1.8	*1.7	*2.9	*0.9	*2.6	*0.9	---	1.6
			Tvetenia	M	---	3.3	---	2.6	2.6	0.9	---	---
			Zavrelimyia	M	---	1.7	---	---	2.6	---	0.8	0.8
		Empididae	*n/a*	T	*0.9	*2.5	---	*5.3	---	---	---	---
			Clinocera	T	5.5	---	---	---	2.6	2.6	2.4	---
			Hemerodromia	T	---	0.8	---	---	---	---	---	---
			Neoplasta	I	---	---	---	---	---	---	0.8	---
		Simuliidae	*Prosimulium*	I	---	---	---	0.9	---	---	---	---
			Simulium	M	1.8	0.8	---	3.5	---	---	3.2	2.5
		Tipulidae	*Antocha*	T	---	---	---	---	---	---	1.6	---
			Tipula	M	2.8	---	---	---	0.9	0.9	---	0.8
	Ephemeroptera	Ephemerellidae	*Eurylophella*	M	---	---	---	---	0.9	---	---	---
		Siphlonuridae	*Siphlonurus*	T	---	---	---	---	---	---	---	0.8
	Hemiptera	Veliidae	*Microvelia*	M	---	---	---	---	0.9	---	---	---
	Odonata	Calopterygidae	*Calopteryx*	T	0.9	0.8	---	---	1.7	---	0.8	---
		Coenagrionidae	*Argia*	T	---	0.8	---	---	---	---	---	---
		Gomphidae	*Stylogomphus*	I	---	---	---	1.8	---	---	---	---
		Libellulidae	*Pachydiplax*	T	---	0.8	---	---	---	---	---	---
	Plecoptera	Nemouridae	*Amphinemura*	I	---	---	---	0.9	---	---	---	---
	Trichoptera	Glossosomatidae	*Glossosoma*	I	---	---	---	---	---	---	0.8	---
		Hydropsychidae	*n/a*	T	---	---	---	*1.8	---	---	---	---
			Cheumatopsyche	T	1.8	---	2.9	3.5	3.4	1.8	2.4	---
			Diplectrona	I	7.3	---	---	2.6	---	---	0.8	0.8
			Hydropsyche	T	5.5	1.7	1.0	5.3	1.7	1.8	2.4	0.8
		Philopotamidae	*Chimarra*	M	8.3	1.7	1.0	1.8	19.0	7.0	10.4	8.2
		Psychomyiidae	*Lype*	M	---	---	---	---	---	---	0.8	---
Mollusca	Basommatophora	Physidae	*Physa*	T	---	---	---	---	---	0.9	---	0.8

Tolerance values are represented as I, M, or T. Intolerant taxa with tolerance values from 0 to 3 are represented by I. Moderately tolerant taxa with tolerance values from 3.1 to 6.9 are represented by M. Tolerant genera with tolerance values from 7 to 10 are represented by T.

* Taxa not identified to genus.

ATKI-004-X

ATKI-004-X in spring 2015

Coordinates

Latitude	*Longitude*
39.48969	76.33089

Land Use

	Catchment	
Acres	90	
	% of Catchment	
Land Cover Type	*2001 NLCD*	*2011 NLCD*
Forest	24.9	21.5
Agriculture	13.8	2.2
Urban	61.1	76.3
Other	0.3	0

Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale. Score ranges are: 0-5 (poor), 6-10 (marginal), 11-15 (sub-optimal) and 16-20 (optimal)

Parameter	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Instream habitat (0-20)	16	9	16	15	11	13	12
Epifaunal substrate (0-20)	13	12	17	13	9	14	11
Velocity/Depth Diversity (0-20)	11	11	15	13	8	13	11
Pool Quality (0-20)	9	11	15	15	8	11	11
Riffle Quality (0-20)	14	7	15	11	8	14	11
Shading (%)	80	85	85	80	70	80	85
Embeddedness (%)	25	35	20	55	45	20	20
Discharge (cfs)	0.08	0.08	0.23	0.15	0.02	2.24	0.21
Bank Erosion (m^2)*	104.5	109.8	16.8	130.4	85.4	33.1	115.0

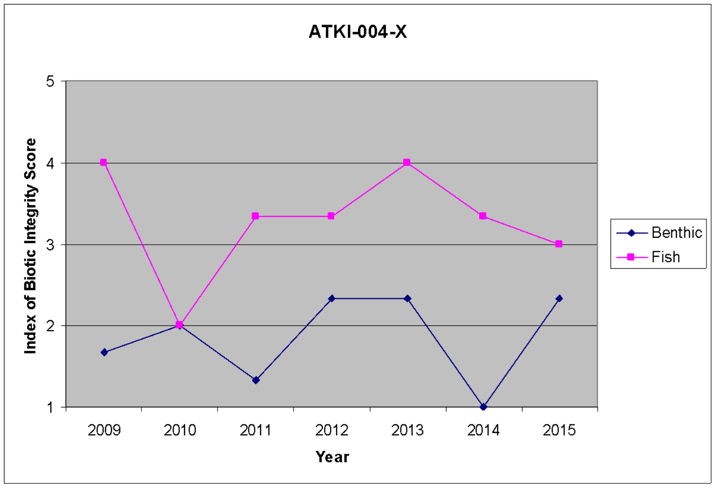
* = Total area of eroded stream banks (sum of left and right banks)

Biology

Indexes of Biotic Integrity.

	Score						
Metric	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
BIBI	1.67	2.00	1.33	2.33	2.33	1.00	2.33
FIBI	4.00	2.00	3.33	3.33	4.00	3.33	3.00

IBI scores less than 2 are rated very poor, 2 to 2.9 are rated poor, 3 to 3.9 are rated fair, and 4 to 5 are rated good.



Fish species collected and their annual abundance.

Species	*Tolerance*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Blue ridge sculpin	I	38	0	14	15	50	37	24
Creek chub	T	7	71	102	69	147	99	61
Blacknose dace	T	2	24	55	53	86	58	117

Tolerance values are represented as I, M, or T. Intolerant species are represented by I, moderately tolerant species are represented by M, and tolerant species are represented by T.

Crayfish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Virile crayfish *(Orconectes virilis)*	14	9	7	19	3	8	8

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Anura (Frogs and Toads)	Northern green frog	A	A	P	P	P	A	P
	Eastern American toad	A	P	A	A	A	A	A
	Pickerel frog	A	A	A	A	A	P	A
Caudata (Salamanders and Newts)	Northern dusky salamander	P	P	P	P	A	A	A
	Northern red salamander	P	A	A	P	A	A	A
	Northern two-lined salamander	P	P	P	P	P	P	P
	Psuedotriton sp.	A	P	A	A	A	A	A

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*Tolerance*	*2009 RA*	*2010 RA*	*2011 RA*	*2012 RA*	*2013 RA*	*2014 RA*	*2015 RA*
Annelida	Haplotaxida	Naididae	*n/a*	T	---	---	*2.1	---	---	---	---
	Lumbriculida	Lumbriculidae	*n/a*	M	*1.9	---	---	---	---	---	---
	Tubificida	Tubificidae	*n/a*	T	---	*1.6	---	---	---	---	---
			Spirosperma	M	---	---	0.9	---	---	---	---
Arthropoda	Amphipoda	Crangonyctidae	*Stygobromus*	M	---	0.8	---	---	---	---	---
	Coleoptera	Dytiscidae	*Neoporus*	M	---	---	1.1	---	---	---	---
		Elmidae	*Stenelmis*	T	0.9	0.8	6.4	0.9	7.0	1.7	5.0
		Hydrophilidae	*Hydrobius*	M	0.9	---	---	---	---	---	---
	Collembola	Isotomidae	*Isotomurus*	M	---	---	---	1.9	0.9	---	---
	Diptera	Chironomidae	*n/a*	M	*0.9	---	---	---	---	---	---
			Ablabesmyia	T	0.9	---	---	---	---	---	2.5
			Chaetocladius	T	4.7	---	---	4.7	---	---	---
			Corynoneura	M	---	0.8	1.1	---	---	---	---
			Cricotopus	T	---	---	---	---	3.5	---	---
			Diamesa	T	---	---	1.1	---	---	---	---
			Diamesinae	T	---	---	---	---	*0.9	*1.7	---
			Dicrotendipes	T	0.9	---	1.1	---	---	---	---
			Eukiefferiella	M	---	18.3	---	13.2	---	0.9	---
			Micropsectra	I	0.9	22.2	---	3.8	---	---	---
			Orthocladiinae	T	*4.7	*0.8	*4.3	---	*1.7	*1.7	*4.2
			Orthocladius	T	40.6	8.7	44.7	10.4	40.9	45.3	33.3
			Parametriocnemus	M	3.8	---	---	---	---	0.9	0.8
			Paraphaenocladius	M	---	3.2	---	3.8	---	---	---
			Paratanytarsus	T	0.9	---	---	---	---	---	---
	Diptera	Chironomidae	*Phaenopsectra*	T	---	---	1.1	---	---	---	---
			Polypedilum	M	1.9	11.9	2.1	7.5	---	---	0.8
			Potthastia	I	---	---	---	0.9	---	---	---
			Rheocricotopus	M	---	0.8	---	---	---	---	---
			Rheotanytarsus	T	1.9	---	3.2	3.8	0.9	---	6.7
			Sympotthastia	T	---	---	1.1	---	3.5	17.1	---
			Tanypodinae	T	*0.9	---	---	---	---	---	*1.7
			Tanytarsini	M	---	---	---	*0.9	---	---	---
			Tanytarsus	M	0.9	---	1.1	14.2	0.9	---	1.7
			Thienemanniella	M	---	2.4	---	---	---	0.9	---
			Thienemannimyia Group	T	*6.6	*1.6	*8.5	*1.9	*6.1	*0.9	*5.0
			Tvetenia	M	---	0.8	---	7.5	3.5	3.4	---
			Zavrelimyia	M	---	0.8	2.1	---	---	---	1.7
		Dasyheleinae	*Dasyhelea*	M	---	---	2.1	---	---	---	---
		Empididae	*Clinocera*	T	0.9	---	---	---	---	0.9	---
			Hemerodromia	T	---	0.8	1.1	---	---	---	---
		Simuliidae	*Simulium*	M	---	1.6	---	---	---	---	5.0
		Tipulidae	*Antocha*	T	0.9	0.8	---	0.9	---	---	---
			Tipula	M	3.8	---	1.1	---	0.9	0.9	0.8
	Ephemeroptera	Baetidae	*Baetis*	M	---	0.8	---	---	---	---	---
		Ephemerellidae	*Eurylophella*	M	---	---	---	---	0.9	---	---
	Hemiptera	Veliidae	*Microvelia*	M	---	---	---	---	---	---	0.8
	Megaloptera	Corydalidae	*Nigronia*	I	---	---	---	---	---	---	0.8
	Odonata	Aeshnidae	*Aeshna*	M	0.9	---	---	---	---	---	---
		Calopterygidae	*Calopteryx*	T	0.9	---	2.1	---	1.7	---	1.7
		Gomphidae	*n/a*	I	---	---	*1.1	---	---	---	---
	Plecoptera	Nemouridae	*Amphinemura*	I	---	0.8	---	3.8	---	---	3.3
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	T	0.9	4.0	6.4	4.7	5.2	3.4	---
			Diplectrona	I	11.3	---	---	3.8	3.5	6.0	0.8
			Hydropsyche	T	---	1.6	1.1	1.9	2.6	4.3	9.2
		Lepidostomatidae	*Lepidostoma*	I	---	---	---	---	---	---	0.8
		Limnephilidae	*Ironoquia*	M	---	---	---	---	---	---	0.8
		Philopotamidae	*n/a*	I	---	---	---	---	---	---	*0.8
			Chimarra	M	4.7	1.6	3.2	6.6	13.9	10.3	10.0
			Dolophilodes	I	---	4.0	---	0.9	---	---	---
		Polycentropodidae	*Nyctiophylax*	I	0.9	---	---	---	---	---	---
Mollusca	Basommatophora	Physidae	*Physa*	T	---	3.2	---	---	0.9	---	1.7

Tolerance values are represented as I, M, or T. Intolerant taxa with tolerance values from 0 to 3 are represented by I. Moderately tolerant taxa with tolerance values from 3.1 to 6.9 are represented by M. Tolerant genera with tolerance values from 7 to 10 are represented by T.

* Taxa not identified to genus.

ATKI-006-X

ATKI-006-X in spring 2015

Coordinates

Latitude	*Longitude*
39.49126	76.32814

Land Use

	Catchment	
Acres	57	
	% of Catchment	
Land Cover Type	*2001 NLCD*	*2011 NLCD*
Forest	22.0	18.9
Agriculture	5.8	0
Urban	72.2	81.1
Other	0	0

Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale. Score ranges are: 0-5 (poor), 6-10 (marginal), 11-15 (sub-optimal) and 16-20 (optimal).

Parameter	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Instream habitat (0-20)	9	7	14	10	7	8	6
Epifaunal substrate (0-20)	6	6	13	11	6	7	5
Velocity/Depth Diversity (0-20)	7	7	9	3	7	8	11
Pool Quality (0-20)	8	8	9	10	7	9	11
Riffle Quality (0-20)	8	7	8	6	9	10	6
Shading (%)	65	60	95	95	65	70	80
Embeddedness (%)	20	20	20	60	35	40	30
Discharge (cfs)	0.02	0.05	0.09	0.01	0.02	0.04	0.10
Bank Erosion (m^2)*	68.5	86.2	18.4	69.0	100.8	83.3	20.5

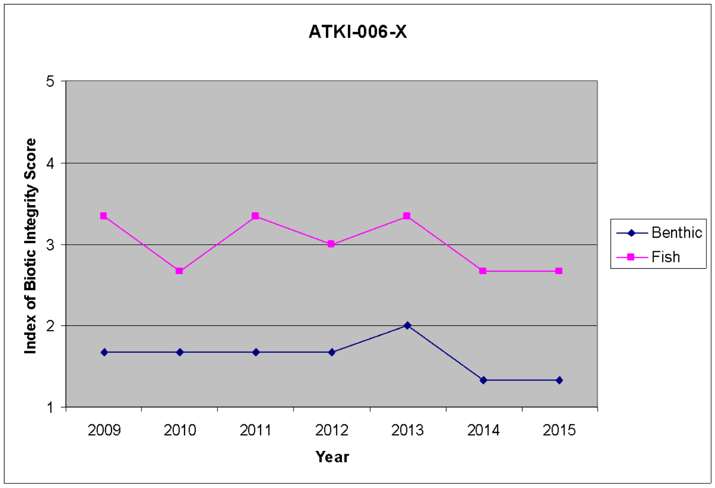
* = Total area of eroded stream banks (sum of left and right banks)

Biology

Indexes of Biotic Integrity.

	Score						
Metric	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
BIBI	1.67	1.67	1.69	1.67	2.00	1.33	1.33
FIBI	3.33	2.67	3.33	3.00	3.33	2.67	2.67

IBI scores less than 2 are rated very poor, 2 to 2.9 are rated poor, 3 to 3.9 are rated fair, and 4 to 5 are rated good.



Fish species collected and their annual abundance.

Species	*Tolerance*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Blue ridge sculpin	I	5	0	2	2	4	0	1
Creek chub	T	98	112	143	72	140	112	78
Blacknose dace	T	21	40	20	46	32	51	15

Tolerance values are represented as I, M, or T. Intolerant species are represented by I, moderately tolerant species are represented by M, and tolerant species are represented by T.

Crayfish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Devil crawfish *(Cambarus diogenes)*	1	0	0	0	0	0	0
Virile crayfish *(Orconectes virilis)*	1	3	0	10	14	5	5

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Anura (Frogs and Toads)	Northern green frog	P	P	A	P	A	A	P
	Pickerel frog	P	P	A	A	A	A	A
	Gray treefrog	A	A	A	P	A	A	A
Caudata (Salamanders and Newts)	Northern dusky salamander	A	P	A	P	P	P	P
Squamata (Snakes and Lizards)	Northern watersnake	A	A	P	A	A	A	A

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*Tolerance*	*2009 RA*	*2010 RA*	*2011 RA*	*2012 RA*	*2013 RA*	*2014 RA*	*2015 RA*
Annelida	Haplotaxida	Enchytraeidae	*n/a*	T	---	---	*1.8	---	---	---	---
		Naididae	*n/a*	T	---	*0.8	---	*0.8	0.9	---	---
	Lumbriculida	Lumbriculidae	*n/a*	M	*2.2	---	*10..9	*6.7	*1.7	*2.2	*4.8
	Tubificida	Tubificidae	*n/a*	T	*1.1	*11.7	*12.7	*3.3	---	---	*1.6
Arthropoda	Coleoptera	Dryopidae	*Helichus*	M	---	---	---	---	---	---	0.8
		Elmidae	*Stenelmis*	T	2.2	---	---	0.8	1.7	7.8	12.1
	Diptera	Chironomidae	*Chaetocladius*	T	---	---	---	---	---	---	3.2
			Chironomus	M	---	0.8	---	---	---	---	---
			Corynoneura	M	---	2.5	---	---	---	---	---
			Dicrotendipes	T	---	---	---	---	---	---	0.8
			Eukiefferiella	M	---	7.5	---	23.3	1.7	---	---
			Hydrobaenus	T	---	---	1.8	---	---	---	---
			Krenosmittia	I	---	---	---	---	---	---	0.8
			Limnophyes	T	---	---	---	3.3	---	1.1	---
			Micropsectra	I	1.1	11.7	---	15.8	---	---	---
			Natarsia	M	---	---	1.8	---	---	---	---
			Orthocladiinae	T	*6.5	*8.3	---	*2.5	*1.7	---	*4.0
			Orthocladius	T	22.6	33.3	9.1	21.7	6.0	14.4	42.7
			Polypedilum	M	2.2	5.8	---	1.7	---	---	---
			Potthastia	I	---	---	---	5.0	---	---	---
			Rheotanytarsus	T	---	---	---	---	0.9	---	0.8
			Tanypodinae	T	*3.2	*1.7	---	---	---	---	---
			Thienemannimyia Group	T	*16.1	*5.8	*12.7	*1.7	*17.9	*30.0	*14.5
			Tvetenia	M	---	0.8	---	0.8	0.9	2.2	---
			Zavrelimyia	M	---	---	---	1.7	0.9	1.1	---
		Empididae	*Hemerodromia*	T	1.1	0.8	---	---	---	---	---
		Simuliidae	*Simulium*	M	---	2.5	---	---	---	---	---
		Tipulidae	*Antocha*	T	---	0.8	1.8	---	1.7	4.4	0.8
			Tipula	M	---	---	1.8	0.8	5.1	6.7	0.8
	Hemiptera	Belostomatidae	*Belostoma*	T	---	---	---	---	---	---	0.8
	Odonata	Calopterygidae	*Calopteryx*	T	---	0.8	1.8	0.8	1.7	---	0.8
	Megaloptera	Corydalidae	*Nigronia*	I	3.2	---	---	---	0.9	---	2.4
	Plecoptera	Leuctridae	*Leuctra*	I	---	---	---	---	0.9	---	---
		Nemouridae	*Amphinemura*	I	1.1	---	---	---	---	---	---
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	T	17.2	1.7	16.4	---	6.8	3.3	---
			Diplectrona	I	1.1	---	---	---	---	2.2	2.4
			Hydropsyche	T	10.8	---	12.7	0.8	2.6	2.2	0.8
		Philopotamidae	*Dolophilodes*	I	1.7	2.5	---	1.7	---	---	---
			Chimarra	M	---	---	14.5	---	44.4	15.5	3.2
Mollusca	Basommatophora	Physidae	*Physa*	T	---	---	---	6.7	0.9	30.0	1.6
Nemertea	Hoplonemertea	Tetrastemmatidae	*Prostoma*	T	0.9	---	---	---	---	---	---

Tolerance values are represented as I, M, or T. Intolerant taxa with tolerance values from 0 to 3 are represented by I. Moderately tolerant taxa with tolerance values from 3.1 to 6.9 are represented by M. Tolerant genera with tolerance values from 7 to 10 are represented by T.

* Taxa not identified to genus.

ATKI-101-X

ATKI-101-X in spring 2016

Coordinates

Latitude	*Longitude*
39.48219	76.34022

Land Use

	Catchment	
Acres	393	
	% of Catchment	
Land Cover Type	*2001 NLCD*	*2011 NLCD*
Forest	34.7	23.7
Agriculture	19.0	5.0
Urban	46.1	67.8
Other	0.3	3.5

Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale. Score ranges are: 0-5 (poor), 6-10 (marginal), 11-15 (sub-optimal) and 16-20 (optimal).

Parameter	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Instream habitat (0-20)	12	13	17	8	15	16	9	16
Epifaunal substrate (0-20)	15	13	18	8	14	14	11	16
Velocity/Depth Diversity (0-20)	9	9	15	8	9	11	12	14
Pool Quality (0-20)	8	8	15	7	7	11	11	13
Riffle Quality (0-20)	14	9	19	12	12	13	11	15
Shading (%)	80	85	90	80	70	80	85	90
Embeddedness (%)	40	40	5	80	25	30	20	30
Discharge (cfs)	0.85	0.98	0.67	0.54	0.42	0.69	0.25	0.28
Bank Erosion (m^2)*	98.1	88.4	60.2	124.0	175.6	125.2	97.2	180.0

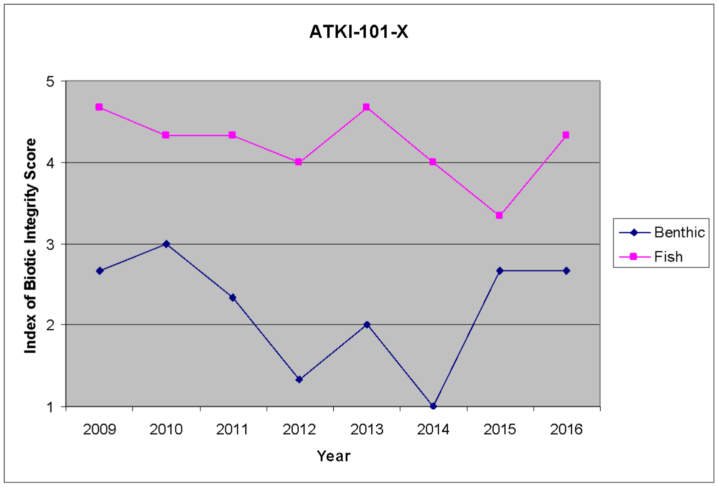
* = Total area of eroded stream banks (sum of left and right banks)

Biology

Indexes of Biotic Integrity.

	Score							
Metric	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
BIBI	2.67	3.00	2.33	1.33	2.00	1.00	2.67	2.67
FIBI	4.67	4.33	4.33	4.00	4.67	4.00	3.33	4.33

IBI scores less than 2 are rated very poor, 2 to 2.9 are rated poor, 3 to 3.9 are rated fair, and 4 to 5 are rated good.



Fish species collected and their annual abundance.

Species	*Tolerance*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Blue ridge sculpin	I	342	217	94	58	169	113	55	195
Common shiner	I	3	3	1	0	1	0	5	10
Creek chub	T	119	114	89	84	69	44	72	55
Blacknose dace	T	87	122	46	33	67	71	85	97
Eastern mosquitofish	M	2	198	11	4	2	0	1	26
Longnose dace	M	3	4	4	2	4	3	6	2
Rosyside dace	M	7	4	7	6	4	5	2	14
Tessellated darter	T	1	1	0	0	0	0	19	14
Brown Bullhead	T	0	4	0	0	0	0	0	0
Fallfish	I	0	38	10	1	0	0	18	5
Bluntnose Minnow	T	0	70	28	3	1	16	77	28
White Sucker	T	0	9	6	2	5	0	48	16
Cutlip Minnow	T	0	0	1	0	0	0	0	0
Redbreast Sunfish	I	0	0	3	2	0	1	1	0
Bluegill	T	0	0	0	3	0	0	0	0
Fathead Minnow	M	0	0	0	0	0	0	0	1
Satinfin shiner	I	0	0	0	0	0	0	0	2
Largemouth bass	T	0	0	0	0	0	0	0	3
Pumpkinseed	T	0	0	0	0	0	0	0	2

Tolerance values are represented as I, M, or T. Intolerant species are represented by I, moderately tolerant species are represented by M, and tolerant species are represented by T.

Crayfish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Common crayfish *(Cambarus bartonii bartonii)*	2	1	0	1	0	0	0	0
Virile crayfish *(Orconecetes virilis)*	64	22	28	66	145	57	31	22

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Anura (Frogs and Toads)	American bullfrog	P	A	A	A	A	A	A	A
	Eastern American toad	P	P	A	A	A	P	P	P
	Fowler's toad	A	P	P	P	A	A	A	A
	Northern green frog	P	P	P	P	P	P	P	P
	Pickerel frog	P	P	A	P	P	A	P	P
	Northern spring peeper	A	A	A	P	P	A	A	A
Caudata (Salamanders and Newts)	Eastern red-backed salamander	A	A	P	A	A	A	A	A
	Northern dusky salamander	P	A	A	P	A	A	A	A
	Northern two-lined-salamander	P	P	A	P	P	P	P	P
Squamata (Snakes and Lizards)	Northern watersnake	P	A	A	A	A	A	A	A
	Queen snake	A	A	A	A	A	A	P	A
Testudines (Turtles)	Eastern snapping turtle	A	P	A	A	A	A	A	A

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*Tolerance*	*2009 RA*	*2010 RA*	*2011 RA*	*2012 RA*	*2013 RA*	*2014 RA*	*2015 RA*	*2016 RA*
Annelida	Haplotaxida	Naididae	*n/a*	T	---	*5.8	*17.7	---	---	---	*0.8	---
	Lumbriculida	Lumbriculidae	*n/a*	M	---	---	---	---	---	---	---	*0.9
Arthropoda	Coleoptera	Elmidae	*Oulimnius*	I	4.8	0.8	0.9	---	---	---	0.8	7.7
			Stenelmis	T	---	---	1.8	---	0.9	0.9	0.8	---
		Dryopidae	*Helichus*	M	---	---	---	---	0.9	---	---	---
		Psephenidae	*Psephenus*	M	2.9	---	0.9	0.9	---	---	---	---
	Diptera	Chironomidae	*n/a*	M	*1.0	---	---	---	---	---	---	---
			Ablabesmyia	T	1.0	---	---	---	---	---	---	---
			Brillia	T	---	---	---	0.9	---	1.7	---	0.9
			Cardiocladius	T	---	---	---	0.9	---	---	---	---
			Chaetocladius	T	---	---	---	6.9	0.9	---	1.6	0.9
			Chironomini	M	---	---	---	---	---	---	---	4.3
			Chironomus	M	---	*0.8	---	---	---	---	---	0.9
			Corynoneura	M	---	2.5	---	---	---	---	---	---
			Cricotopus	T	---	---	---	---	1.8	---	---	---
			Cryptochironomus	T	---	0.8	---	---	---	---	---	---
			Diamesa	T	1.0	0.8	2.7	---	---	---	3.2	4.3
			Diamesinae	T	---	---	---	---	*2.6	---	---	0.9
			Dicrotendipes	T	---	---	---	---	---	---	0.8	---
			Eukiefferiella	M	---	1.7	---	19.8	---	---	---	---
			Hydrobaenus	T	---	0.8	---	---	1.8	---	---	---
			Limnophyes	T	---	0.8	---	---	---	---	---	---
			Mesocricotopus	M	1.0	---	---	---	---	---	---	---
			Micropsectra	I	6.7	3.3	---	2.6	---	---	---	---
			Nanocladius	T	---	---	---	---	0.9	---	---	---
			Orthocladiinae	T	---	*3.3	*5.3	*7.8	---	*6.1	*1.6	---
			Orthocladius	T	19.0	28.1	38.1	37.9	9.6	18.3	20.0	17.2
			Parametriocnemus	M	---	0.8	0.9	---	3.5	0.9	---	---
			Polypedilum	M	1.9	0.8	1.8	---	0.9	0.9	11.2	17.2
			Rheotanytarsus	T	---	---	---	---	1.8	3.5	---	---
			Smittia	M	1.0	---	---	---	---	---	1.6	---
			Sublettea	T	---	---	---	---	---	---	0.8	---
			Sympotthastia	T	---	---	---	---	19.3	58.3	---	---
			Tanytarsini	M	---	---	---	---	---	---	*2.4	---
			Tanytarsus	M	---	---	---	---	2.6	---	1.6	4.3
			Tanypodinae	T	*1.0	*1.7	---	---	---	---	---	---
			Thienemanniella	M	---	3.3	0.9	---	---	---	---	---
			Thienemannimiyia Group	T	---	---	---	---	---	---	---	*1.7
			Tvetenia	M	---	4.1	---	4.3	2.6	0.9	---	0.9
			Zavrelimyia	M	---	0.8	---	---	---	---	---	---
		Empididae	*n/a*	T	*1.9	*1.7	---	*3.4	---	---	---	---
			Clinocera	T	---	---	15.9	---	---	---	---	---
		Simuliidae	*Prosimulium*	I	1.0	---	---	---	---	---	---	0.9
			Simulium	M	1.0	4.1	---	3.4	---	---	---	4.3
		Tipulidae	*Antocha*	T	6.7	0.8	0.9	---	2.6	0.9	0.8	---
			Tipula	M	2.9	---	0.9	1.7	4.4	0.9	0.8	---
	Ephemeroptera	Baetidae	*Acentrella*	M	3.8	2.5	---	4.3	---	---	8.0	6.0
			Baetis	M	---	2.5	---	---	---	---	---	---
	Plecoptera	Nemouridae	*Amphinemura*	I	---	---	0.9	---	---	---	---	2.6
	Trichoptera	Glossosomatidae	*Glossosoma*	I	---	---	0.9	---	---	1.7	21.6	---
		Hydropsychidae	*n/a*	T	*1.0	---	---	---	---	---	---	2.6
			Cheumatopsyche	T	10.5	---	6.2	---	24.6	3.5	18.4	6.9
			Diplectrona	I	1.0	---	---	0.9	---	---	---	1.7
			Hydropsyche	T	10.5	2.5	1.8	---	7.0	0.9	1.6	13.8
		Philopotamidae	*Chimarra*	M	13.3	0.8	1.8	---	11.4	0.9	0.8	1.7
			Dolophilodes	I	4.8	24	---	0.9	---	---	---	---
Platyhelminthes	Tricladida	Dugesiidae	*Girardia*	I	1.0	---	---	2.6	---	---	0.8	---

Tolerance values are represented as I, M, or T. Intolerant taxa with tolerance values from 0 to 3 are represented by I. Moderately tolerant taxa with tolerance values from 3.1 to 6.9 are represented by M. Tolerant genera with tolerance values from 7 to 10 are represented by T.

* Taxa not identified to genus.

ATKI-102-X

ATKI-102-X in spring 2016

Coordinates

Latitude	*Longitude*
39.48827	76.33401

Land Use

	Catchment	
Acres	146	
	% of Catchment	
Land Cover Type	*2001 NLCD*	*2011 NLCD*
Forest	15.7	13.1
Agriculture	18.6	0
Urban	65.7	82.3
Other	0	4.6

Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale. Score ranges are: 0-5 (poor), 6-10 (marginal), 11-15 (sub-optimal) and 16-20 (optimal)

Parameter	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Instream habitat (0-20)	12	10	16	10	13	12	12	8
Epifaunal substrate (0-20)	11	13	17	8	13	13	13	9
Velocity/Depth Diversity (0-20)	11	11	14	12	11	9	11	11
Pool Quality (0-20)	11	11	14	13	11	7	12	11
Riffle Quality (0-20)	9	8	10	11	11	12	14	6
Shading (%)	75	70	80	75	55	60	80	40
Embeddedness (%)	40	40	5	55	40	35	40	20
Discharge (cfs)	0.19	0.16	0.05	0.25	0.06	0.52	0.44	0.09
Bank Erosion (m^2)*	66.3	81.5	37.8	70.0	44.2	82.6	86.9	0.8

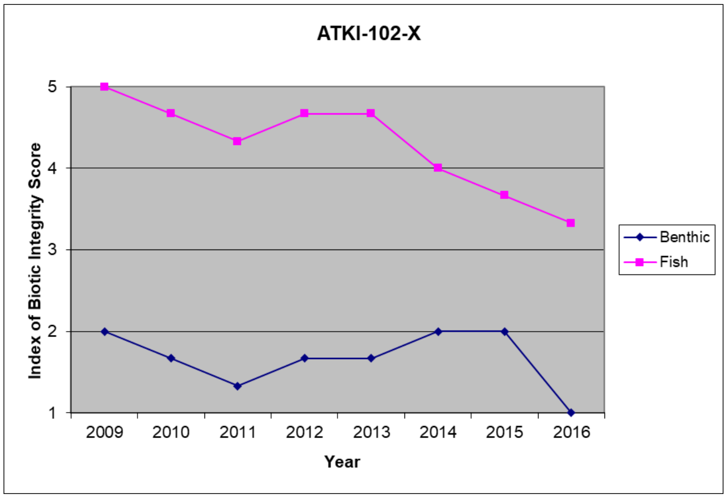
* = Total area of eroded stream banks (sum of left and right banks)

Biology

Indexes of Biotic Integrity.

	Score							
Metric	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
BIBI	2.00	1.67	1.33	1.67	1.67	2.00	2.00	2.67
FIBI	5.00	4.67	4.33	4.67	4.67	4.00	3.67	3.33

IBI scores less than 2 are rated very poor, 2 to 2.9 are rated poor, 3 to 3.9 are rated fair, and 4 to 5 are rated good.



Fish species collected and their annual abundance.

Species	*Tolerance*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Blue ridge sculpin	I	320	199	142	157	163	159	80	45
Creek chub	T	144	139	112	109	165	103	101	147
Blacknose dace	T	111	144	129	107	130	277	136	430

Tolerance values are represented as I, M, or T. Intolerant species are represented by I, moderately tolerant species are represented by M, and tolerant species are represented by T.

Crayfish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Common crayfish *(Cambarus bartonii bartonii)*	1	4	0	0	0	0	0	0
Virile crayfish *(Orconecetes virilis)*	2	6	5	16	10	15	7	3
Unknown Procambarus *(Procambarus sp.)*	1	0	0	2	0	0	0	0

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Anura (Frogs and Toads)	Eastern American toad	A	P	A	A	A	A	A
	Northern green frog	P	P	P	A	P	P	P
	Pickerel frog	P	P	A	P	A	A	A
	Northern spring peeper	A	A	A	A	P	A	A
	Cope's gray treefrog	A	A	A	A	P	A	A
	Gray treefrog	A	A	A	A	A	A	P
Caudata (Salamanders and Newts)	Northern red salamander	P	P	A	P	A	A	A
	Northern two-lined salamander	P	P	P	P	P	P	P
	Northern dusky salamander	A	P	A	P	A	A	A
Testudines (Turtles)	Eastern painted turtle	A	A	A	A	A	P	A
	Eastern snapping turtle	A	A	A	A	A	P	A

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*Tolerance*	*2009 RA*	*2010 RA*	*2011 RA*	*2012 RA*	*2013 RA*	*2014 RA*	*2015 RA*	*2016 RA*
Annelida	Haplotaxida	Naididae	*n/a*	T	---	*1.8	---	---	*7.3	---	---	*5.6
		Tubificdae	*n/a*	T	---	---	*0.8	---	*0.9	*0.9	*0.8	---
	Lumbriculida	Lumbriculidae	*n/a*	M	*0.9	---	---	---	---	---	3.1	---
Arthropoda	Coleoptera	Elmidae	*Optioservus*	M	---	0.6	---	---	---	---	---	---
			Oulimnius	I	4.5	---	---	---	0.9	0.9	---	---
			Stenelmis	T	12.7	---	4.0	1.0	2.7	---	5.5	0.8
		Psephenidae	*Psephenus*	M	0.9	---	---	---	---	---	---	---
	Collembola	Isotomidae	*Isotomurus*	M	---	---	---	---	---	0.9	---	---
	Diptera	Ceratopogonidae	*n/a*	M	---	---	*1.6	---	---	---	---	---
		Chironomidae	*Chaetocladius*	T	27.3	---	4.0	2.9	---	---	---	1.6
			Chironomus	M	---	---	---	---	---	---	---	21.6
			Cryptochironomus	T	---	---	---	---	---	---	0.8	---
			Corynoneura	M	---	0.6	---	---	---	---	---	0.8
			Cricotopus	T	---	1.2	---	---	---	---	---	---
			Diamesa	T	---	---	9.6	---	---	---	16.4	2.4
			Diamesinae	T	---	---	---	---	---	---	---	2.4
			Dicrotendipes	T	---	---	0.8	2.9	---	---	---	---
			Eukiefferiella	M	---	11.2	---	1.9	---	---	---	0.8
			Limnophyes	T	---	---	---	2.9	---	---	---	---
			Micropsectra	I	0.9	20.1	---	---	---	---	---	4.0
			Orthocladiinae	T	*2.7	*4.1	*9.6	*1.9	*0.9	*0.9	---	*7.2
			Orthocladius	T	14.5	22.5	56.0	31.7	50.9	20.9	11.7	48.8
			Parametriocnemus	M	---	---	---	2.9	---	---	0.8	---
			Paratanytarsus	T	---	---	1.6	1.9	---	---	---	---
			Polypedilum	M	2.7	1.2	0.8	15.4	---	1.8	19.5	---
			Potthastia	I	---	---	---	3.8	---	---	---	---
			Rheocricotopus	M	---	---	---	---	---	---	---	0.8
			Rheotanytarsus	T	2.7	---	---	---	2.7	3.6	1.6	---
			Sympotthastia	T	---	---	---	---	---	0.9	---	---
			Tanypodinae	T	---	*0.6	---	---	---	---	---	---
			Tanytarsini	M	---	---	---	---	*0.9	---	*2.3	---
			Tanytarsus	M	---	---	---	1.0	2.7	---	9.4	0.8
			Thienemanniella	M	---	1.2	---	---	---	---	---	0.8
			Thienemannimyia Group	T	*0.9	---	---	---	---	*0.9	---	---
			Tvetenia	M	---	1.8	---	13.5	1.8	3.6	---	1.6
			Zavrelimyia	M	---	0.6	---	---	---	---	---	---
		Empididae	*n/a*	T	---	*0.6	---	*1.0	---	*0.9	---	---
			Clinocera	T	2.7	---	0.8	---	---	---	---	---
			Hemerodromia	T	---	---	---	1.0	---	---	---	---
		Simuliidae	*Simulium*	M	---	1.8	---	1.0	---	---	---	---
		Tipulidae	*Antocha*	T	0.9	---	0.8	---	0.9	2.7	---	---
			Tipula	M	---	0.6	---	---	1.8	0.9	2.3	---
	Ephemeroptera	Baetidae	*Baetis*	M	---	3.0	---	---	---	---	---	---
			Acentrella	M	---	---	---	1.0	---	---	---	---
	Odonata	Coenagrionidae	*Argia*	T	---	---	---	---	---	0.9	---	---
	Trichoptera	Glossosomatidae	*Glossosoma*	I	---	---	---	---	---	---	10.2	---
		Hydropsychidae	*n/a*	T	---	---	---	---	---	*1.8	---	---
			Cheumatopsyche	T	4.5	---	---	5.8	12.7	13.6	7.0	---
			Diplectrona	I	4.5	---	0.8	---	---	0.9	---	---
			Hydropsyche	T	11.8	1.8	3.2	1.0	4.5	9.1	5.5	---
		Philopotamidae	*n/a*	I	---	---	---	*1.0	---	---	---	---
			Chimarra	M	4.5	1.2	4.8	4.8	7.3	30.9	1.6	---
			Dolophilodes	I	---	12.4	---	---	---	---	---	---
		Polycentropodidae	*Nyctiophylax*	I	---	---	---	---	0.9	---	---	---
Mollusca	Basommatophora	Physidae	*Physa*	T	---	---	0.8	---	---	0.9	0.8	---
	Veneroida	Pisidiidae	*Musculium*	M	---	---	---	---	---	0.9	---	---
Nematomorpha	Gordioidea	Gordiidae	*n/a*	M	---	---	---	---	---	---	*0.8	---
Platyhelminthes	Tricladida	Dugesiidae	*Girardia*	T	---	---	---	---	---	0.9	---	---

Tolerance values are represented as I, M, or T. Intolerant taxa with tolerance values from 0 to 3 are represented by I. Moderately tolerant taxa with tolerance values from 3.1 to 6.9 are represented by M. Tolerant genera with tolerance values from 7 to 10 are represented by T.

* Taxa not identified to genus.

ATKI-105-X

ATKI-105-X in spring 2015

Coordinates

Latitude	Longitude
39.49187	76.33392

Land Use

	Catchment	
Acres	107	
	% of Catchment	
Land Cover Type	2001 NLCD	2011 NLCD
Forest	17.4	16.1
Agriculture	19.9	0
Urban	62.7	77.7
Other	0	6.3

Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale. Score ranges are: 0-5 (poor), 6-10 (marginal), 11-15 (sub-optimal) and 16-20 (optimal).

Parameter	2009	2010	2011	2012	2013	2014	2015
Instream habitat (0-20)	12	12	14	8	8	12	8
Epifaunal substrate (0-20)	10	9	12	6	7	13	10
Velocity/Depth Diversity (0-20)	12	11	8	8	7	7	11
Pool Quality (0-20)	12	12	9	6	7	7	12
Riffle Quality (0-20)	11	8	7	8	9	11	8
Shading (%)	40	25	55	40	40	30	60
Embeddedness (%)	60	40	20	70	65	20	64
Discharge (cfs)	0.11	0.05	0.05	1.98	0.12	0.11	0.19
Bank Erosion (m^2)*	130.0	95.2	6.5	111.3	159.9	13.6	32.8

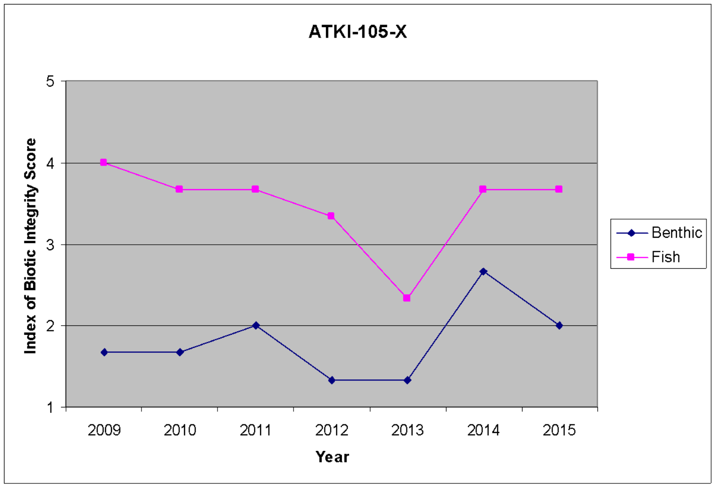
* = Total area of eroded stream banks (sum of left and right banks)

Biology

Indexes of Biotic Integrity.

	Score						
Metric	2009	2010	2011	2012	2013	2014	2015
BIBI	1.67	1.67	2.00	1.33	1.33	2.67	2.00
FIBI	4.00	3.67	3.67	3.33	2.33	3.67	3.67

IBI scores less than 2 are rated very poor, 2 to 2.9 are rated poor, 3 to 3.9 are rated fair, and 4 to 5 are rated good.



Fish species collected and their annual abundance.

Species	*Tolerance*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Blue ridge sculpin	I	7	2	2	5	0	6	3
Creek chub	T	317	182	121	116	92	67	152
Blacknose dace	T	132	192	29	20	125	71	166

Tolerance values are represented as I, M, or T. Intolerant species are represented by I, moderately tolerant species are represented by M, and tolerant species are represented by T.

Crayfish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Virile crayfish *(Orconecetes virilis)*	4	0	0	0	4	6	10
Unknown Procambarus *(Procambarus sp.)*	5	2	11	21	1	8	0

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Anura (Frogs and Toads)	Northern green frog	P	P	P	P	P	P	P
	Pickerel frog	P	A	A	A	A	A	P
	Cope’s gray treefrog	A	A	A	P	A	A	A
	American bullfrog	A	A	A	A	A	P	A
Caudata (Salamanders and Newts)	Northern two-lined salamander	P	P	A	P	P	P	A
Testundines (Turtles)	Eastern snapping turtle	A	A	P	A	A	A	A

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*Tolerance*	*2009 RA*	*2010 RA*	*2011 RA*	*2012 RA*	*2013 RA*	*2014 RA*	*2015 RA*
Annelida	Haplotaxida	Enchytraeidae	*n/a*	T	---	---	*0.8	---	---	---	---
			Limnodrilus	T	1.0	---	---	---	---	---	---
		Naididae	*n/a*	T	---	---	*0.8	*0.8	*67.8	---	---
	Lumbriculida	Lumbriculidae	*n/a*	M	---	---	*1.6	*4.7	*0.8	---	---
	Tubificida	Tubificidae	*n/a*	T	---	*4.5	*6.5	*7.0	*0.8	*1.7	*8.8
Arthropoda	Coleoptera	Elmidae	*Dubiraphia*	M	---	---	---	---	---	---	0.9
			Stenelmis	T	11.3	1.8	16.1	---	0.8	5.2	13.2
		Psephenidae	*Psephenus*	M	---	---	---	---	---	---	0.9
	Diptera	Chironomidae	*Brillia*	T	---	0.9	---	---	---	---	---
			Dicrotendipes	T	4.1	---	0.8	---	0.8	0.9	2.6
			Chironomini	M	---	*0.9	*0.8	---	---	---	---
			Chironomus	M	---	2.7	---	---	---	---	---
			Corynoneura	M	---	---	---	---	0.8	---	---
			Cricotopus	T	---	---	---	---	7.6	0.9	---
			Cryptochironomus	T	---	---	---	---	---	---	0.9
			Diamesa	T	---	---	---	---	---	0.9	---
			Endochironomus	M	1.0	---	---	---	---	---	---
			Eukiefferiella	M	---	17.0	---	3.9	---	---	---
			Hydrobaenus	T	---	---	4.0	---	---	---	---
			Limnophyes	T	---	1.8	---	0.8	0.8	---	---
			Micropsectra	I	---	15.2	---	---	---	---	7.0
			Orthocladiinae	T	*4.1	*2.7	*2.4	*6.2	*1.7	---	*0.9
			Orthocladius	T	38.1	33.9	37.1	48.1	10.2	0.9	17.5
			Paratanytarsus	T	---	0.9	0.8	---	2.5	4.3	---
			Phaenopsectra	T	---	---	0.8	---	---	---	---
			Polypedilum	M	2.1	---	---	13.2	---	---	3.5
			Potthastia	I	---	---	---	0.8	---	---	---
			Prodiamesa	M	---	0.9	---	---	---	---	---
			Rheotanytarsus	T	---	0.9	2.4	---	1.7	---	0.9
			Tanypodinae	T	---	---	*1.6	---	---	---	0.9
			Tanytarsus	M	---	---	---	---	0.8	---	---
			Thienemannimyia Group	T	*4.1	*0.9	*5.6	---	---	*1.7	*1.8
			Tvetenia	M	---	6.3	---	---	2.5	2.6	1.8
			Zavrelimyia	M	---	0.9	---	---	---	---	---
		Empididae	*n/a*	T	---	---	---	---	---	---	*0.9
			Hemerodromia	T	---	1.8	---	2.3	---	---	1.8
		Simuliidae	*Simulium*	M	---	1.8	---	---	---	0.9	---
		Tipulidae	*Antocha*	T	---	---	---	---	---	---	0.9
			Erioptera	M	1.0	---	---	---	---	---	---
			Limonia	M	---	---	---	---	---	0.9	---
			Tipula	M	1.0	---	---	---	---	1.7	---
	Odonata	Aeshnidae	*Boyeria*	M	---	---	---	---	---	---	0.9
		Calopterygidae	*Calopteryx*	T	---	---	2.4	---	---	0.9	---
		Coenagrionidae	*n/a*	T	*1.0	---	---	---	---	---	---
			Argia	T	---	---	---	0.8	---	0.9	---
	Trichoptera	Hydropsychidae	*n/a*	T	---	---	---	*1.6	---	---	---
			Cheumatopsyche	T	6.2	0.9	4.0	7.0	---	35.7	15.8
			Hydropsyche	T	24.7	3.6	4.8	1.6	---	14.8	15.8
		Philopotamidae	*Chimarra*	M	---	---	4.0	1.6	---	24.3	2.6
		Polycentropodidae	*Nyctiophylax*	I	---	---	---	---	---	0.9	---
Mollusca	Basommatophora	Lymnaeidae	*n/a*	M	---	---	*0.8	---	---	---	---
	Veneroida	Pisidiidae	*Musculium*	M	---	---	0.8	---	---	---	---

Tolerance values are represented as I, M, or T. Intolerant taxa with tolerance values from 0 to 3 are represented by I. Moderately tolerant taxa with tolerance values from 3.1 to 6.9 are represented by M. Tolerant genera with tolerance values from 7 to 10 are represented by T.

* Taxa not identified to genus.

ATKI-107-X

ATKI-107-X in spring 2015

*Sampling did not occur in 2013 due to construction

Coordinates

Latitude	*Longitude*
39.49452	76.33070

Land Use

	Catchment	
Acres	50	
	% of Catchment	
Land Cover Type	*2001 NLCD*	*2011 NLCD*
Forest	30.4	27.4
Agriculture	8.8	0
Urban	60.8	66.4
Other	0	6.3

Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale. Score ranges are: 0-5 (poor), 6-10 (marginal), 11-15 (sub-optimal) and 16-20 (optimal).

Parameter	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Instream habitat (0-20)	3	7	4	5	X	5	10
Epifaunal substrate (0-20)	3	11	10	5	X	7	9
Velocity/Depth Diversity (0-20)	6	10	8	6	X	6	7
Pool Quality (0-20)	6	7	5	8	X	6	6
Riffle Quality (0-20)	6	9	6	9	X	6	12
Shading (%)	25	10	20	5	X	25	30
Embeddedness (%)	70	10	20	60	X	30	50
Discharge (cfs)	0.04	0.22	0.06	0.05	0.01	0.02	0.22
Bank Erosion (m^2)*	11.7	21.2	0.64	32.7	X	5.6	7.8

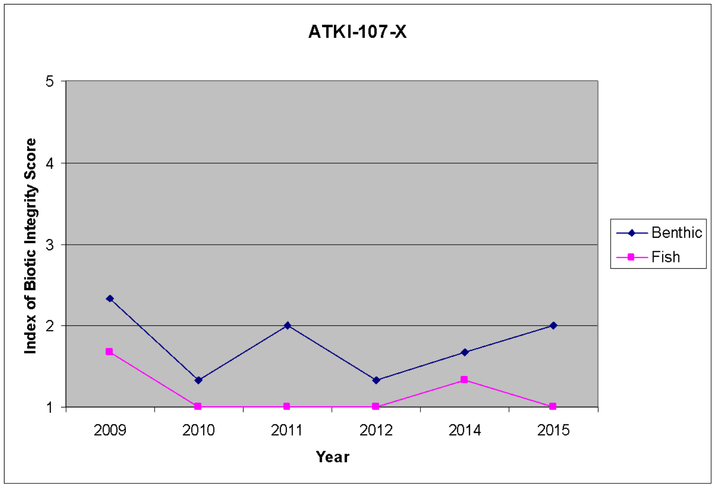
* = Total area of eroded stream banks (sum of left and right banks)

Biology

Indexes of Biotic Integrity.

	Score						
Metric	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
BIBI	2.33	1.33	2.00	1.33	X	1.67	1.33
FIBI	1.67	1.00	1.00	1.00	X	1.33	1.00

IBI scores less than 2 are rated very poor, 2 to 2.9 are rated poor, 3 to 3.9 are rated fair, and 4 to 5 are rated good.



Fish species collected and their annual abundance.

Species	*Tolerance*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Creek chub	T	1	0	0	0	X	1	0
Blacknose dace	T	0	0	0	0	X	1	0

Tolerance values are represented as I, M, or T. Intolerant species are represented by I, moderately tolerant species are represented by M, and tolerant species are represented by T.

Crayfish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Devil crawfish *(Cambarus Diogenes)*	P	0	0	1	X	0	0
Unknown Cambarus *(Cambarus sp.)*	1	0	0	0	X	0	0
Unknown Procambarus *(Procambarus sp.)*	5	19	8	32	X	3	2
Orconectes virilis	0	0	9	0	X	0	0

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Anura (Frogs and Toads)	American bullfrog	P	A	A	A	A	A	A
	Northern green frog	A	P	A	A	A	P	P
	Pickerel frog	A	A	A	P	P	P	A
Caudata (Salamanders and Newts)	Northern two-lined salamander	P	P	A	P	P	P	A
Squamata (Snakes and Lizards)	Queen snake	A	A	A	P	A	A	A

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*Tolerance*	*2009 RA*	*2010 RA*	*2011 RA*	*2012 RA*	*2013 RA*	*2014 RA*	*2015 RA*
Annelida	Haplotaxida	Enchytraeidae	*n/a*	T	---	*0.8	---	---	---	---	---
		Naididae	*n/a*	T	---	---	---	*6.0	---	---	---
	Tubificida	Tubificidae	*n/a*	T	*2.2	*0.8	---	*1.7	---	---	---
	Lumbriculida	Lumbriculidae	*n/a*	M	*2.2	*1.6	*5.0	---	---	---	*4.2
Arthropoda	Coleoptera	Elmidae	*Stenelmis*	T	---	---	---	---	---	---	0.8
		Psephenidae	*Psephenus*	M	---	---	---	---	---	---	1.7
	Collembola	Isotomidae	*Isotomurus*	M	---	---	0.8	---	---	1.7	---
	Decapoda	Cambaridae	*Procambarus*	I	---	---	---	---	---	---	0.8
	Diptera	Ceratopogonidae	*n/a*	M	---	---	*0.8	---	---	*0.8	---
		Chironomidae	*Alotanypus*	M	---	---	---	---	---	---	0.8
			Brillia	T	---	---	---	0.9	---	---	---
			Chironomus	M	---	0.8	24.8	---	---	---	---
			Cricotopus	T	4.3	19.5	0.8	13.8	---	5.8	2.5
			Diamesa	T	---	---	0.8	---	---	---	10.8
			Dicrotendipes	T	1.1	---	---	---	---	---	---
			Eukiefferiella	M	---	1.6	---	28.4	---	---	---
			Limnophyes	T	---	---	---	0.9	---	0.8	---
			Micropsectra	I	---	0.8	---	2.6	---	---	---
			Orthocladiinae	T	---	*4.9	*0.8	*1.7	---	*2.5	*2.5
			Orthocladius	T	3.2	57.7	2.5	19.0	---	9.2	35.8
			Parametriocnemus	M	---	1.6	---	---	---	---	---
			Paratanytarsus	T	---	---	0.8	---	---	---	---
			Polypedilum	M	1.1	---	---	0.9	---	---	2.5
			Tanytarsini	M	---	---	---	---	---	---	*0.8
			Thienemannimyia Group	T	*2.2	---	*2.5	---	---	23.3	3.3
			Tvetenia	M	---	0.8	---	1.7	---	0.8	---
			Zavrelimyia	M	---	---	0.8	---	---	---	---
		Empididae	*Hemerodromia*	T	1.1	0.8	---	---	---	---	---
		Simuliidae	*Simulium*	M	---	---	---	0.9	---	---	---
		Sciomyzidae	*n/a*	M	---	---	---	*0.9	---	---	---
		Tipulidae	*n/a*	M	*1.1	---	---	---	---	---	---
			Antocha	T	1.1	---	---	---	---	---	---
			Tipula	M	1.1	---	0.8	0.9	---	---	1.7
	Odonata	Coenagrionidae	*Argia*	T	2.2	---	1.7	0.9	---	---	---
	Trichoptera	Hydropsychidae	*n/a*	T	*1.1	---	---	*1.7	---	---	*0.8
			Cheumatopsyche	T	28	1.6	16.5	4.3	---	20.8	8.3
			Hydropsyche	T	41.0	2.4	38.8	0.9	---	4.2	10.0
		Philopotamidae	*Chimarra*	M	---	0.8	1.7	0.9	---	26.7	10.8
			Dolophilodes	I	---	---	---	4.3	---	---	---
Mollusca	Basommatohora	Ancylidae	*Ferrissia*	T	---	---	---	---	---	1.7	---
		Physidae	*Physa*	T	2.2	---	---	6.9	---	3.9	1.7

Tolerance values are represented as I, M, or T. Intolerant taxa with tolerance values from 0 to 3 are represented by I. Moderately tolerant taxa with tolerance values from 3.1 to 6.9 are represented by M. Tolerant genera with tolerance values from 7 to 10 are represented by T.

* Taxa not identified to genus.

LWIN-108-X

LWIN-108-X in spring 2016

Coordinates

Latitude	*Longitude*
39.46891	76.32773

Land Use

	Catchment	
Acres	412	
	% of Catchment	
Land Cover Type	*2001 NLCD*	*2011 NLCD*
Forest	23.4	23.9
Agriculture	26.1	2.6
Urban	50.5	73.0
Other	0.1	0.5

Physical Habitat

Physical habitat parameters are scored on a 0 (poor) to 20 (optimal) scale. Score ranges are: 0-5 (poor), 6-10 (marginal), 11-15 (sub-optimal) and 16-20 (optimal).

Parameter	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Instream habitat (0-20)	14	14	17	16	11	15	15	11
Epifaunal substrate (0-20)	16	15	16	11	12	16	15	11
Velocity/Depth Diversity (0-20)	9	8	14	15	11	12	12	12
Pool Quality (0-20)	7	9	14	16	11	11	12	11
Riffle Quality (0-20)	13	14	15	14	8	15	16	13
Shading (%)	85	85	65	90	80	75	85	90
Embeddedness (%)	20	20	10	55	40	20	20	50
Discharge (cfs)	0.33	0.69	1.97	0.97	0.22	0.62	1.64	0.64
Bank Erosion (m^2)*	84.8	110.6	80.2	134.4	158.4	63.0	126.0	185.0

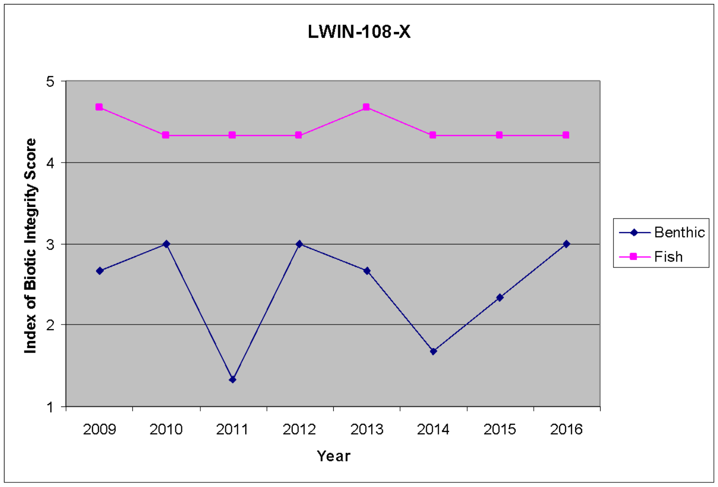
* = Total area of eroded stream banks (sum of left and right banks)

Biology

Indexes of Biotic Integrity.

	Score							
Metric	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
BIBI	2.67	3.00	1.33	3.00	2.67	1.67	2.33	3.00
FIBI	0.67	4.33	4.33	4.33	4.67	4.33	4.33	4.33

IBI scores less than 2 are rated very poor, 2 to 2.9 are rated poor, 3 to 3.9 are rated fair, and 4 to 5 are rated good.



Fish species collected and their annual abundance.

Species	*Tolerance*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
American eel	T	2	5	4	8	4	7	8	10
Blue ridge sculpin	I	161	274	140	102	148	88	77	114
Creek chub	T	68	129	77	55	72	31	36	56
Blacknose dace	T	80	149	40	52	101	34	45	108
Longnose dace	M	2	6	5	8	8	4	8	8
Margined madtom	I	1	1	1	10	15	7	15	11
Rosyside dace	M	28	18	10	28	40	12	36	48
White sucker	T	2	2	2	1	5	3	0	11
Fallfish	I	0	5	0	0	0	0	1	1
Smallmouth Bass	M	0	1	0	0	0	0	0	1
Bluntnose Minnow	T	0	4	3	9	2	3	2	8
River chub	I	0	0	0	1	1	0	0	1
Redbreast sunfish	I	0	0	0	1	25	6	1	0
Pumpkinseed	T	0	0	0	1	0	0	0	0
Tessellated darter	T	0	0	0	0	3	0	2	0
Common shiner	I	0	0	0	0	0	0	0	7
Largemouth bass	T	0	0	0	0	0	0	0	2

Tolerance values are represented as I, M, or T. Intolerant species are represented by I, moderately tolerant species are represented by M, and tolerant species are represented by T.

Crayfish species collected and their annual abundance.

Species	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Common crayfish *(Cambarus bartonii bartonii)*	4	5	3	1	6	0	4	1
Devil crawfish *(Cambarus diogenes)*	0	0	0	0	0	1	0	0
Virile crayfish *(Orconecetes virilis)*	2	0	1	13	0	3	3	3
Spiny Cheek crayfish *(Orconecetes limosus)*	0	8	9	1	11	0	5	0

Herpetofauna (P) presence or (A) absence.

Order (Common)	*Species*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Anura (Frogs and Toads)	Eastern American toad	P	A	A	A	A	P	A	A
	Wood frog	P	A	A	A	A	A	P	A
	Northern green frog	A	P	A	A	P	A	A	P
	Pickerel frog	A	A	A	A	P	A	A	A
Caudata (Salamanders and Newts)	Eastern red-backed salamander	A	A	P	A	A	A	A	A
	Northern two-lined salamander	P	P	A	P	P	P	P	P
	Northern red salamander	A	A	A	A	A	P	A	A
	Northern dusky salamander	A	A	A	A	A	A	P	A
Squamata (Snakes and Lizards)	Northern ring-necked snake	P	A	A	A	A	A	A	A
	Northern watersnake	A	A	A	P	A	A	A	A
Testudines (Turtles)	Eastern box turtle	P	A	A	A	P	A	A	A

Benthic macroinvertebrates collected and their annual relative abundance. (genera (RA)) = (number of genera (percent relative abundance)).

Phylum	*Order*	*Family*	*Genus*	*Tolerance*	*2009 RA*	*2010 RA*	*2011 RA*	*2012 RA*	*2013 RA*	*2014 RA*	*2015 RA*	*2016 RA*
Annelida	Haplotaxida	Naididae	*n/a*	T	---	*0.9	*3.2	---	*8.8	---	---	---
	Lumbriculida	Lumbriculidae	*n/a*	M	*4.8	---	---	---	*1.0	---	---	---
Arthropoda	Coleoptera	Dytiscidae	*Neoporous*	M	---	---	---	---	---	---	---	0.8
		Elmidae	*Ancyronyx*	T	---	---	---	---	---	---	---	0.8
		Ptilodactylidae	*Anchytarsus*	M	---	---	---	---	---	---	---	0.8
	Diptera	Chironomidae	*Ablabesmyia*	T	---	---	---	0.9	1.0	---	0.9	0.8
			Brillia	T	---	---	2.4	0.9	1.0	1.7	---	2.5
			Chaetocladius	T	9.6	---	---	---	---	---	---	---
			Chironominae	M	---	---	---	---	---	*0.9	---	---
			Chironomini	M	---	---	---	---	---	---	*1.9	*1.7
			Corynoneura	M	---	---	1.6	0.9	---	---	---	---
			Cricotopus	T	1.9	---	---	---	---	---	---	---
			Diamesa	T	---	0.9	---	---	3.9	5.2	3.7	0.8
			Diamesinae	T	---	---	---	---	---	---	---	0.8
			Eukiefferiella	M	---	0.9	---	5.2	---	0.9	---	0.8
			Hydrobaenus	T	6.7	---	21.8	---	12.7	3.5	---	3.3
			Micropsectra	I	7.7	2.6	4.0	1.7	---	2.6	---	---
			Orthocladiinae	T	*5.8	*2.6	*2.4	*3.5	---	*4.3	*2.8	*2.5
			Orthocladius	T	11.5	30.7	39.5	20.9	2.9	28.7	48.1	9.2
			Parametriocnemus	M	---	1.8	---	---	5.9	3.5	0.9	---
			Phaenopsectra	T	---	---	---	---	---	1.7	---	---
			Polypedilum	M	2.9	0.9	8.9	6.1	1.0	0.9	6.5	16.7
			Potthastia	I	---	---	---	1.7	---	---	---	---
			Rheocricotopus	M	---	---	---	---	2.9	---	---	0.8
			Rheotanytarsus	T	---	---	0.8	---	1.0	3.5	---	---
			Sympotthastia	T	---	9.6	---	---	1.0	8.7	---	---
			Synorthocladius	M	---	---	---	---	---	1.7	---	---
			Tanytarsini	M	---	---	---	---	---	---	*1.9	*0.8
			Tanytarsus	M	---	---	---	---	1.0	0.9	---	0.8
			Tanypodinae	T	---		---	---	---	---	*0.9	---
			Thienemanniella	M	---	0.9	4.0	---	---	2.6	---	---
			Thienemannimyia Group	T	*1.0	---	*0.8	---	---	*0.9	---	0.8
			Trissopelopia	M	1.0	---	---	---	---	---	---	---
			Tvetenia	M	---	5.3	---	3.5	6.9	7.0	---	0.8
			Zavrelimyia	M	---	---	---	---	---	0.9	---	---
		Empididae	*n/a*	T	*1.0	*0.9	---	*12.2	---	---	*0.9	---
			Clinocera	T	4.8	---	2.4	1.7	---	---	0.9	0.8
		Simuliidae	*Simulium*	M	1.9	2.6	0.8	5.2	---	---	0.9	2.5
			Prosimulium	I	---	---	---	0.9	---	---	---	---
		Psychodidae	*n/a*	M	---	---	---	---	---	---	---	*0.8
		Tipulidae	*n/a*	M	*1.0	---	---	---	---	---	---	---
			Antocha	T	---	---	---	0.9	---	---	4.6	---
			Dicranota	I	---	---	---	1.0	---	---	---	---
			Tipula	M	1.9	0.9	0.8	0.9	3.9	---	1.9	---
	Ephemeroptera	Baetidae	*Acentrella*	M	---	---	---	3.5	---	---	---	---
		Ephemerellidae	*Eurylophella*	M	2.9	0.9	---	1.7	2.0	---	---	0.8
		Heptageniidae	*n/a*	I	---	---	---	---	---	---	0.9	---
			Maccaffertium	I	---	---	---	---	1.0	---	0.9	---
	Odonata	Gomphidae	*Stylogomphus*	I	---	---	---	---	1.0	---	---	---
	Plecoptera	Leuctridae	*n/a*	I	---	---	*1.6	---	---	---	---	1.6
			Leuctra	I	---	---	0.8	---	---	---	---	---
		Nemouridae	*Amphinemura*	I	3.8	---	---	0.9	---	---	12.0	10.8
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	T	7.7	---	1.6	2.6	27.5	8.7	3.7	7.5
			Diplectrona	I	8.7	2.6	0.8	---	---	---	0.9	0.8
			Hydropsyche	T	---	1.8	---	0.9	---	0.9	---	5.8
		Limnephilidae	*n/a*	M	---	---	---	---	---	*0.9	---	---
			Ironoquia	M	1.0	---	---	---	---	---	0.9	---
			Pycnopsyche	M	---	---	0.8	---	---	---	---	---
		Philopotamidae	*n/a*	I	---	---	---	---	---	---	*1.9	---
			Chimarra	M	2.9	1.8	---	---	9.8	8.7	1.9	3.3
			Dolophilodes	I	4.8	28.9	---	21.7	---	0.9	---	15.8
		Polycentropididae	*Polycentropus*	I	3.8	---	---	---	---	---	---	---
			Neureclipsis	I	---	---	---	---	1.0	---	---	---
		Psychomyiidae	*Lype*	M	---	---	---	---	1.0	---	---	---
		Uenoidae	*Neophylax*	I	---	---	---	1.0	---	---	---	---
Mollusca	Basommatophora	Ancylidae	*Ferrissia*	T	---	---	---	---	---	---	---	0.8
		Lymnaeidae	*Stagnicola*	T	---	---	---	---	---	---	---	0.8
	Veneroida	Pisidiidae	*n/a*	M	*1.0	---	---	---	---	---	---	---

Musculium	M	---	---	0.8	---	---	---	---	---

Tolerance values are represented as I, M, or T. Intolerant taxa with tolerance values from 0 to 3 are represented by I. Moderately tolerant taxa with tolerance values from 3.1 to 6.9 are represented by M. Tolerant genera with tolerance values from 7 to 10 are represented by T.

* Taxa not identified to genus.